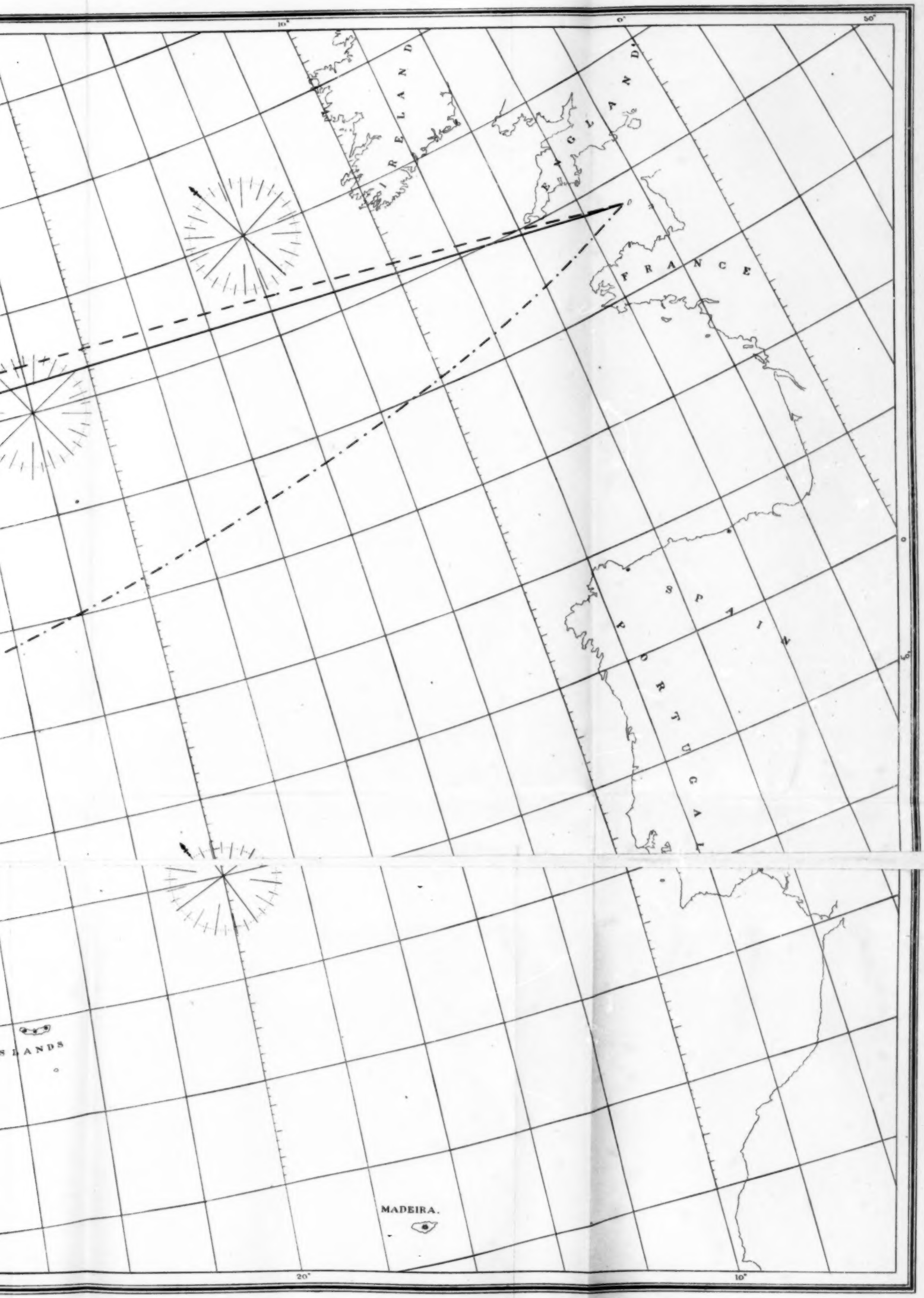
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NOTES ON THE LITERATURE OF EXPLOSIVES.*

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No. VI.

In No. V of these Notes we have referred to Berthelot's lectures on Explosives. These have now been reprinted by Van Nostrand as No. 70 of his *Science Series*. We then proposed to present later his discussion of the theories suggested to account for explosions induced by the influence of contiguous explosions, and hence we extract the following.

In discussing the duration and speed of propagation of explosive reactions Berthelot has regarded the development of the explosive reactions either from the point of view of their duration in a homogeneous system in which all the parts are maintained at the same temperature, or else from the standpoint of their propagation in a system equally homogeneous, to which fire is applied directly by means of a body in ignition, or else by a violent shock. In these later years, however, the study of explosive substances has revealed the existence of another method of propagating the reactions from an explosive centre, this propagation taking place at a distance and by the intermediation of the air or certain solid bodies which do not themselves participate in the chemical change.

We shall now speak of what are called explosions by influence, whose existence was formerly suspected from certain known facts connected with the simultaneous explosion of several buildings separated by considerable space from each other, as in catastrophes

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

occurring in powder mills. Attention has been especially directed to this class of phenomena by the study of nitro-glycerine and gun-cotton.

We will begin by giving the most important characteristic facts. A dynamite cartridge made to detonate by means of a fulminate cap causes the adjoining cartridges to detonate, not only by contact and by direct shock, but even from a distance. In this way an indefinite number of cartridges, arranged in a regular course, may be made to detonate.

The distances to which the explosion may be propagated are relatively great. Thus, for instance, with cartridges contained in rigid metallic envelopes and placed on a resisting soil, the detonation produced by 100 grams of Vonges dynamite (75 per cent. of nitro-glycerine and 25 per cent. randanite, which is very finely divided silica) communicates itself 0.3 meter, according to the experiments of Captain Coville. D being equal to the distance in meters and C the weight of the charge in kilograms, the experiments of this officer show that $D = 3.0C$. When the caps were laid on a rail D was found to be equal to $7.0C$. On soft or ploughed-up earth the distances, on the contrary, are less. When a cartridge is suspended in air there is no detonation by influence, perhaps because the cartridge not being fixed can recoil freely, which diminishes the violence of the shock. Nevertheless there are experiments which show that the air suffices for the transmission of the detonation by influence, although with greater difficulty and requiring a greater mass of the explosive. With a dynamite less rich in nitro-glycerine (55 per cent. of nitro-glycerine and 45 per cent. of the argillaceous ashes of bog-head coal), contained in similar cartridges, and placed along the ground, the experiments of Captain Pamard have given the smallest distances: $D = 0.90C$. If metallic envelopes having less resistance are used, the distance at which the explosion is propagated is likewise diminished. Dynamite simply spread along the ground ceases to propagate the explosion. The experiments performed in Austria have given similar results. They have shown that the explosion is communicated either in the free air with intervals of 4 cm., or else through pine boards 18 mm. thick. In a lead tube with a diameter $= 0.15$ meter and a meter in length, a cartridge placed at one extremity has caused the detonation of a cartridge at the other end. The explosion is still better transmitted through tubes made with wrought iron. The couplings of the tube diminish its aptitude for transmission.

An explosion which is propagated in this manner will go on weakening itself from cartridge to cartridge and even change its character. Thus according to the experiments made by Captain Müntz at Versailles, in 1872, a first charge of dynamite exploded directly, excavated a funnel-shaped hole in the ground with a radius of 0.30 meter; the second charge, detonated by influence, produced an opening of only 0.22 meter; the effect of the detonation was then reduced. This reduction should manifest itself towards the limit of the distance at which the influence ceases. In the same way four tin screens were located 40 mm. apart, a small cylinder of gun-cotton was placed against each of them, and the entire affair arranged on a board; 15 mm. in front of the first screen a similar cylinder was detonated. All of the cylinders detonated, but a progressive diminution was observed in the indentations produced in the board below each cylinder. According to these facts the propagation by influence depends at the same time on the pressure acquired by the gas and on the nature of the support. It is not even necessary that it should be rigid.

Finally, in operating under water at a depth of 1.30 meters, a charge of 5 kilograms of dynamite brought on an explosion of a charge of 4 kilograms situated at a distance of 3 meters. The water then transmits the explosive shock, at least to a certain distance, as does a solid body. This transmission is so violent that the fish are killed in ponds within a sphere of a certain radius by the explosion of a dynamite cartridge.*

Similar experiments have been made by Abel with compressed gun-cotton. According to his observations the explosion of the first block determines that of a series of similar blocks. The propagation under water has likewise been studied; the explosion of a torpedo charged with fulminating cotton caused the detonation of adjoining torpedoes placed within a certain radius of activity. The sudden pressure transmitted by the water when measured by means of the compression of lead at different distances, such as 2.50 m., 3.50 m., 4.50 m., 5.50 m., goes on decreasing, as would be expected. Besides, experiment has shown that the relative position of the charge and of the "crusher" is of no consequence, which is in harmony with the principle of equal transmission in all directions of hydraulic pressures.

* For further data, see Abbot's Submarine Mines, pages 54 and 122.

Explosions of fulminating substances which are rapidly propagated to a great number of caps, belong to this same order of explosions by influence. We have previously cited the explosion in the Rue Beranger.* The experiments which M. Sarrau made on that occasion showed that caps of the description which produced this catastrophe may be successively burned in a fire without giving rise to a general explosion; whereas the explosion of a few of these same caps, each containing 10 milligrams of explosive material, if it is provoked by a rapid pressure, determines by influence the explosion of the adjoining packages, even when they are not contiguous and are situated at a distance of 15 centimeters apart. A general explosion may thus easily be produced by influence. It follows then from these facts, and especially from the experiments made under water, that the explosions by influence are not due to inflammation, properly so called, but to the transmission of a shock arising from the enormous and sudden pressures produced by the nitro-glycerine or the gun-cotton.

Let us enlarge upon this explanation; it is the same fundamentally as that which we have already shown as accounting for the influence of the shock which determines the direct detonation of explosive substances.

In an extremely rapid reaction, the pressures may approach to the limit which corresponds to the matter detonating in its own volume, and the commotion due to the sudden development of almost theoretical pressures can be propagated both through the ground and supports as intermediary, or through the air itself, projected *en masse*, as has been shown by the explosion of certain powder factories and of gun-cotton magazines, and even by some of the experiments with dynamite and compressed gun-cotton. The intensity of the shock propagated either by a column of air or by a liquid or solid mass varies with the nature of the explosive body and its mode of inflammation; it is of greater violence according as the length of the chemical reaction is shorter and develops more gas, that is to say, a higher initial pressure, and more heat, and consequently work, for the same weight of explosive material.

This transmission of a shock is conveyed better by solids than by liquids, better by liquids than by gases; with gases it becomes better as they are more compressed. Through solids it is better propagated according to their degree of hardness, iron transmitting

* Nav. Inst. Proc. 9, 752.

it better than earth, and hard ground better than ploughed soil. All breaks of continuity in the transmitting material tend to weaken it, especially if a softer substance is interposed. Thus it is that the use of a tube made from a goose-quill, as a receiver, stops the effect of mercury fulminate, while a tube or a capsule of copper transmits this effect in all its intensity. The explosion by influence is the better propagated in a series of cartridges according as the envelope of the first detonating cartridge is the more resisting, which allows the gases to attain a greater pressure before the covering is destroyed. The existence of an empty space, that is to say, filled only with air, between the fulminate and the dynamite, on the other hand diminishes the violence of the shock transmitted, and in consequence that of the explosion; generally the effects of breaking powders are lessened when there is no contact. To form a full conception of the transmission of sudden pressures which produce shock by the supporting medium, it is desirable to recall this general principle, in virtue of which, in a homogeneous mass, pressures are transmitted equally in all directions, and are the same on a small element of surface whatever its position. Detonations produced under water with gun-cotton show that this principle is equally applicable to the sudden pressures which produce the explosive phenomena. But it ceases to be true when one passes from one medium to another.

If the inert chemical matter which transmits the explosive movement is fixed in a given situation on the surface of the ground, or better, on the surface of the rail on which the first cartridge was placed, or better still, held by the pressure of a mass of deep water in the midst of which the first detonation is produced, the propagation of the movement in this matter will hardly be able to take place, except under the form of a wave of a purely physical order, and consequently of an essentially different character from the first wave of a chemical and physical order simultaneously developed in the explosive body itself. This new wave propagates the concussion away from the explosive centre all around it, and with an intensity which decreases inversely as the square of the distance. Even in the neighborhood of the centre, the displacements of the molecules may break the cohesion of the mass and disperse it, or crush it by enlarging the chamber of explosion, if the operation is conducted in a cavity. But at a very short distance (the magnitude of which depends on the elasticity of the surrounding medium) these movements, confused at the beginning, arrange themselves in such order as to produce a wave,

properly so called, characterized by compressions and sudden deformations of the material, the amplitude of these oscillations depending upon the magnitude of the initial impulse. They move with a very great rapidity, and preserve their regularity up to the point where the medium is broken; then these compressions and sudden deformations change their nature and are transformed into a movement of impulse, that is to say, they reproduce the shock. If then they act on a new cartridge they may determine its explosion; the shock will be otherwise weakened by the distance, and in consequence the character of the explosion may be modified. The effects diminish in this manner up to a certain point from which the explosion ceases to produce itself. When this occurs on a second cartridge the same series of effects will be produced from the second to the third cartridge; but they depend on the character of the explosion of the second cartridge. And thus it goes on.

Such is the theory that appears to me to explain explosions by influence and the phenomena which accompany them. It depends, definitely, on the production of two orders of waves: one series represents the explosive waves, properly so called, developed in the midst of the matter which detonates, and consists of a continually reproduced transformation of the chemical actions into thermal and mechanical actions, which transmit the shock to the support and to the contiguous bodies; the other is a purely mechanical and physical series, which transmits equally the sudden pressure all around the centre of the concussion to the adjoining bodies, and by a singular circumstance to a new mass of explosive material.

A theory differing from this was originally proposed by Abel. It is the theory of *Synchronous vibrations*. According to this English savant the originating cause of the detonation of an explosive lies in this synchronism between the vibrations produced by the body which provokes the detonation and those which the first body would produce in detonating, precisely as a violin string resounds at a distance in unison with another vibrating chord. Prof. Abel has recited the following facts in support of his theory. To begin with, the detonators appear to differ with each variety of explosive. For instance, nitrogen iodide cannot cause the detonation of compressed gun-cotton. Nitrogen chloride will not produce the same detonation except when ten times as much weight is used as of the fulminate necessary. Likewise nitro-glycerine will not produce a detonation in sheets of gun-cotton on which is placed a case containing nitro-glycerine. In

this way nitro-glycerine up to 23.3 grams can be detonated without effect. On the other hand, 7.75 grams of compressed gun-cotton have caused the detonation, at a distance of 25 mm., of nitro-glycerine wrapped up in an envelope of thin sheet-iron. Likewise, according to Brown, a cap filled with a mixture of potassium ferrocyanide and potassium chlorate will not detonate gun-cotton. Finally, according to Trauzl, a cap consisting of a mixture of mercury fulminate and potassium chlorate should be of much heavier weight than if it be filled with the pure fulminate; nevertheless, the heat given off by the same weight is greater by one-fifth with the first mixture.

Messrs. Champion and Pellet have brought to the support of this ingenious hypothesis the following experiments: They attached to the strings of a double bass particles of nitrogen iodide, a substance which detonates on the slightest friction. Then they made the strings of a similar instrument vibrate at a short distance off; a detonation was produced, but only for sounds higher than a certain note which corresponds to 60 vibrations per second. They also took two conjugate parabolic mirrors, placed 2.5 meters apart, and they arranged along the line of the foci at different points several drops of nitro-glycerine or of nitrogen iodide; they then detonated at one of the foci a large drop of nitro-glycerine; they observed that the explosive substances placed in the conjugated foci detonated in unison, to the exclusion of the same substances placed at the other points. A layer of lamp-black placed on the surface of the mirrors was designed to prevent the reflection and the concentration of the heat-rays.

As yet none of the experiments appear to me to be conclusive, and several of them seem even to be directly opposed to the theory. We shall begin by observing that the characteristic feature of a given musical note, capable of determining each variety of explosion, has never been established. It is only below a certain note that the effects cease to be produced, while they take place by preference, whatever the explosive bodies may be, by the action of the most acute notes. Besides, these effects cease to produce themselves at distances which are incomparably less than the resonance of the chords in unison, which goes to prove that the detonations are functions of the intensity of the mechanical action, rather than of the character of the determining vibration. Similarly, the detonation ceases to be produced when the weight of the detonator is too slight, and in consequence when the mechanical energy of the shock is weakened. Nevertheless, the specific vibratory note which determines the ex-

plosions should always remain the same. For instance, cartridges filled with 75 per cent. of dynamite cease to detonate when the capsule contains a weight of fulminate less than 0.2 gram, the detonation only being assured in all cases by the regulation weight of one gram. This confirms the existence of a direct relation between the character of the detonation and the intensity of the shock produced by one and the same detonator.

If it is true that gun-cotton will cause the nitro-glycerine to detonate in consequence of the synchronism of the vibration communicated, then we do not understand why the reciprocal action does not take place; while the absence of reciprocity can be easily explained by the difference of the structure of the two substances which plays so important a part in the transformation of the mechanical energy into work.

This same diversity of structure and the modifications which it introduces into the transmission of the phenomena of the shock and the transformation of the mechanical energy into thermal energy, may be cited to explain the facts observed by Abel.

The difference between the energy of pure fulminate and of the fulminate mixed with potassium chlorate is no less easily explained; the shock produced by the first body being sharper on account of the absence of all dissociation of the product (which is no other than carbon monoxide), this absence should be contrasted with the dissociation of carbon dioxide formed in the second case. Perhaps, also, the formation of potassium chloride disseminated through the gas produced, with the concurrence of potassium chlorate, weakens the shock, just the same as silicon does in the case of dynamite.

All the effects observed with nitrogen iodide may be explained by the vibration of the supports and by the effects of rubbing which result therefrom, this substance being particularly sensitive to friction. The experiment with the conjugate mirrors may also be easily explained by the concentration in the focus of the movements of the air, and therefore of the mechanical effects which result.

Besides, M. Lambert has proved by experiments made for the Commission on Explosive Substances, that in the explosion of dynamite cartridges in tubes of cast iron of large diameter, regarded from the standpoint of detonations by influence, there does not appear to be any difference between the ventral segments and the nodes characteristic of the tube.

Desiring to clear up this entire question by removing it from the influence of the support and of the diversity of cohesion and physical

structure of solid explosive substances, I undertook a series of special experiments on the chemical stability of matter in sonorous vibration, and especially on that of gaseous bodies such as ozone, hydrogen arsenide, or liquids such as hydrogen peroxide and persulphuric acid, all of these bodies being selected from among those which decompose or change spontaneously at ordinary temperatures with the disengagement of heat, precisely as explosive substances do. The description of these experiments may be found in the *Comptes Rendus* or in the *Revue Scientifique*, May, 1880.

They lead to the conclusion that substances, which are transformable with the disengagement of heat, are stable under the influence of sound waves, while they are decomposed under the influence of ethereal vibrations. This diversity in the mode of action of the two classes of vibrations is not surprising when we consider that the most acute sonorous vibrations are incomparably slower than the luminous or thermal vibrations.

Hence it appears certain that the propagation of explosions by influence is not made in virtue of an undulatory movement, which is a complex motion of a chemical and physical order in the midst of the explosive substance which is decomposed, while it is purely physical in the midst of intermediary substances which suffer no decomposition; but that which distinguishes this sort of movement of the vibrations, properly so called, is, first of all, its extreme intensity, that is to say, the magnitude of the mechanical energy which it transmits; it is also the unique character of the explosive wave, which is propagated in contradistinction with the multiplicity of successive sonorous waves. Finally, it is essential to observe that the explosive material does not detonate because it transmits the movement, but on the contrary because it arrests it, and because it transforms on the spot the mechanical energy into thermal energy, capable of suddenly raising the temperature of the substance up to the degree which will produce its decomposition.

On page 670, Vol. VIII, we have referred to a new explosive called Panclastite, invented by Eugene Turpin. We are now in possession of a brochure* by the inventor, and from this we learn that the substance is made by mixing liquid nitrogen tetroxide (N_2O_4) with com-

*Notice sur la Panclastite découverte par Eugène Turpin. Paris, E. Bernard et Cie, 1882.

bustible substances such as the hydrocarbons; vegetable, animal and mineral oils; fats and their derivatives, but preferably with carbon disulphide. He proposes that the two substances should be kept apart until needed for use, when they may be mixed in the proportions considered best for the work in hand. The proportions which yield the most sensitive mixture are $2CS_2 + 3N_2O_4$, being about two volumes of the first to three volumes of the second. In making this mixture the temperature falls about 20°. When equilibrium is re-established the mixture burns with a most brilliant flame if ignited when freely exposed to the air. If confined in a vessel and ignited it burns until the pressure of the gases produces an explosion. Under these circumstances only a portion of the enclosed matter explodes and the remainder burns up quietly. If however it be exploded by a fulminate primer, whether confined or freely exposed, the explosion is complete and powerful; more powerful, it is claimed, than nitroglycerine or explosive gelatine. The reactions attending these different modes of decomposition vary. When the panclastite burns freely it leaves a deposit of sulphur, and sometimes of colorless crystals which yield nitrogen dioxide when brought in contact with water. When the panclastite is detonated carbon is deposited as a black residue. The author suggests that the reactions made be represented thus:

$$2CS_2 + 3N_2O_4 = 6N + 4SO_2 + 2CO_2,$$

or

$$2CS_2 + 3N_2O_4 = 6N + 4SO_2 + 2C.$$

The deposition of sulphur can only be explained by supposing a deficiency of nitrogen tetroxide. The formation of nitrogen dioxide or monoxide cannot be admitted, since carbon disulphide burns equally well with these two gases.

The advantages claimed for this explosive are greater power than dynamite, perfect safety of the separate constituents in transport and storage, insensitiveness of the mixture to blows, and easy control of the manufacture by the government, owing to the fact that nitrogen tetroxide is not met with in commerce.

The power is shown in the results of several experiments cited, where rocks and rails were broken and cylinders of lead compressed. Thus where 400 grams of dynamite No. 1 broke blocks of stone into 5 or 6 portions, 150 grams of panclastite broke them into 28 to 32 portions. In testing the sensitiveness a hammer weighing six kilograms—

Exploded	gunpowder	in falling	0.50	meters.
"	gun-cotton	"	0.25	"
"	dynamite No. 1	"	0.15	"
"	gum dynamite	"	0.20 to .25	"
"	nitro-glycerine	"	0.10 to .15	"
had not "	panclastite (liquid)	"	4.00	"

The sensitiveness can however be varied at will, and the material used in this experiment was the least sensitive of the mixtures.

In general panclastite is to be used in the liquid state, but if the solid state is preferred it may be absorbed by infusorial silica just as nitro-glycerine is.

M. Turpin proposes to utilize the light-giving power of panclastite, and has devised a lantern for burning the liquids which is very similar in construction to the oxyhydrogen lantern without the lime cylinder. He believes this may be used as a signal or search light in the field or for photographic purposes.

The heat developed by the combustion is also very great, being estimated at about 3000° C. Platinum fuses instantly under the action of this flame, and the mixture can fuse its own weight. Graphite also commences to fuse. Turpin has also devised a furnace by which this source of great heat may be utilized in the arts. All of these devices are represented in large phototypes.

Nitrogen tetroxide may be produced by heating lead nitrate,

$$2Pb(NO_3)_2 = 2PbO + 2N_2O_4 + O_2,$$

by acting on tin with nitric acid,

$$5Sn + 20HNO_3 = H_{10}Sn_5O_{15} + 5H_2O + 10N_2O_4,$$

by acting on nitryl chloride with silver nitrate,

$$NO_2Cl + AgNO_2 = AgCl + N_2O_4,$$

by union of oxygen with nitrogen trioxide,

$$2N_2O_3 + O_2 = 2N_2O_4.$$

When the nitrogen tetroxide gas formed by the above processes is passed into a freezing mixture of salt and ice it condenses in transparent crystals which melt at −9°, and which when once melted do not resolidify until cooled to −30°. Above −9° it forms a mobile liquid (sp. gr. 1.451) which boils at 22°. If water is present in the condenser the substance does not crystallize. Nitrogen tetroxide

probably undergoes dissociation at a comparatively low temperature. At 100° the gas consists chiefly of NO_2, at ordinary temperatures of N_2O_4, and at intermediate temperatures the gas is a varying mixture of these two. The liquid, at ordinary temperatures, gives off an abundance of reddish vapors, which, when mixed with air, are extremely difficult to condense. These vapors have a pungent, suffocating odor, an acid taste, are quite irrespirable, and stain the skin of a bright yellow. When mixed with water at a low temperature it is decomposed into nitric and nitrous acids; at an ordinary temperature, into nitric acid, water, and nitrogen dioxide. The results of the determination of its specific heat are given on page 443, Vol. VIII of these Proceedings. The heat of combination of the gas is —24.3, of the liquid —20.

The *Notes on Explosives* of W. N. Hill have been regarded as a most valuable and trustworthy guide to this study. The recent limited edition having been exhausted, we extract the following new notes, which correct, explain or extend the statements and descriptions of former editions.

The features of the nitro-glycerine process which are of the greatest importance are the strength of the acids and the complete washing of the products. The nitric acid should be of the greatest strength, since upon this depends the completeness of the conversion. With such acid, the maximum production of nitro-glycerine is attained and the oxidizing action is lessened. Also in such case the heat of the operation is much reduced, and the temperature of the reaction becomes of less importance. With the strongest acid the limits of temperature heretofore assigned may be considerably exceeded without injurious result. It has been stated that the mixing of the glycerine with the acid should be slowly performed. This should be understood to mean that the mixing is to be slowly performed, in order to preserve a low temperature during the operation; but, if the temperature is within the limit, the mixing should be performed as rapidly as possible, and the nitro-glycerine removed from the sphere of action. Rapidity of working is largely dependent upon the quality of acids employed, since the heat evolved is least when the strongest acid is used. In general with highly concentrated acid, not only is the proportional product increased, but also the reaction goes on more uniformly and is more easily controlled.

The manufacture of nitric acid for this purpose cannot be considered here, but it should be stated that acid for making nitro-glycerine is

now largely sold in the form of "mixed acid"—that is, the mixture of nitric acid and sulphuric acid ready for use. Much of this, however, does not come up to the standard which should be set up. The degree of strength of the nitric acid given before is too low. Acid of 1.49 to 1.51 specific gravity (48°–49° B.) should be taken, and this strength should be real and not factitious, as is often the case with acids nominally testing 50° and 52° Baume. To prepare such acid requires special care and precaution. The method of redistillation from oil of vitriol in glass retorts furnishes the finest acid, and in the writer's hand has worked extremely well, but it involves some trouble and expense.

The proportion of nitro-glycerine obtained is dependent almost entirely upon the acid used. If the glycerine is weak the product will fall off, but the small difference in strength of glycerine ordinarily found exercises little effect. But if the acids are weak the product is markedly less. This does not depend to any extent upon the method or form of apparatus operated, but only upon the acid taken. Weak acids will carry smaller quantities of glycerine and give lower proportional products than strong ones. Consequently, statements of relative products obtained are of comparatively little value unless accompanied by a statement of the kind of acid employed and the relative amount of glycerine treated. We have stated that in operating practically 1.6 to 1.75 parts of nitro-glycerine to one of glycerine were obtained, but that with the strongest nitric acid 1.96 to 2.03 parts were produced on a small scale. These figures are too low. It is not difficult to practically carry the proportion to rather more than two to one, using one part of glycerine to 7.5 or 8 parts of acid (mixed). With some care in the preparation of materials 2.2 parts can be obtained.

The method of making nitro-glycerine fully described in the body of this work is a convenient one from simplicity of apparatus, and has been found serviceable for the occasional requirements of the torpedo station. But for steady work on a large scale it is not as desirable as other methods of operating. The handling of small quantities of material takes much time and labor, and the reaction goes on more steadily and regularly with larger masses of material. The simplest, and a very effective method, is to use a large amount of the mixed acid (2000 to 3000 lbs.) in a large leaden or iron tub, containing also coils of pipe through which cold water is forced; this tub is set within another of wood, and the annular space between is traversed by

cold water; agitation of the acid is brought about by agitators driven by power (in some cases the agitators are driven by hand, but this is very objectionable). The glycerine is run in through an opening in the cover of the tub and distributed so as to fall upon the acid in a number of fine streams. The temperature is observed by a thermometer passing through the cover. When the desired amount of glycerine has been run in, the contents of the tub are drawn off into water and the nitro-glycerine separated.

In another form of apparatus a leaden tank is placed within a wooden one, so that water can be passed between them; in the tank revolves a hollow shaft, carrying paddles for a portion of its length, and for the remainder a cylinder, so that cold water may be led through the shaft and cylinder. The glycerine falls upon the surface of the revolving cylinder and is so conveyed into the acid, which is agitated by the paddles.

Different in principle is the process of Boutmy * and Faucher. In this the glycerine is mixed with half the sulphuric acid and the mixture allowed to cool. This is then added to the mixed acid (the nitric acid with the remainder of the sulphuric), the whole allowed to stand for twenty-four hours, and then thrown into water to separate the nitro-glycerine. Special advantages are claimed for the method, but it is doubtful if these claims are well founded. It is stated that it is more free from danger than others, and that it gives a large yield. With proper care the operation of conversion is not a dangerous one, and accidents at that stage are extremely rare by any method. The yield claimed is not in advance of that usually obtained, and, as already pointed out, the yield is governed by the quality of the acid used. This method is open to the grave objection that a large proportion of the nitro-glycerine is in contact with strong acid for a considerable time.

In Kurtz's method the vessel containing the acid is a narrow cylinder, with conical bottom of lead or iron, placed vertically. Two pipes extend to the bottom of this cylinder, one delivering glycerine and the other compressed air. The openings of these pipes are opposite to one another, so that the air-current strikes the glycerine and quickly diffuses it through the acid. The nitro-glycerine formed is supposed to rise to the surface of the liquid, and run off through a pipe to the washer. In another form of Kurtz's apparatus air is forced

* Nav. Inst. Proc. 5, 15.

into the glycerine, making a kind of emulsion, which is driven into the acid in the converting vessel by air pressure.

In all forms of apparatus for making nitro-glycerine the greatest care must be taken to prevent any accidental admixture of water with the charge in the converter. A very little water shows itself by the greater trouble and slowness experienced in running, and the product falls off. But if more water enters, the heat developed would be greater than can be carried away by the usual means of cooling and the charge is "fired." Usually this means only an active decomposition, accompanied by clouds of nitrous vapors. Slight "fires" may be stopped by vigorous agitation, but if the firing is persistent the contents of the tub should be run off as rapidly as possible. During drawing off, constant agitation of the liquid should be made to prevent separation of nitro-glycerine. Washing with water is the only mode spoken of. It is not difficult to wash nitro-glycerine thoroughly with water only, but the treatment must be continued until the washing is complete. This requires considerable time and labor. It is usual in manufacturing, therefore, to use an alkaline solution (sodium carbonate) to assist and expedite the washing process.

Hill has heretofore stated that frozen nitro-glycerine could not be fired. This is an error, it can be fired, but with much greater difficulty than when in the liquid state. In many later experiments he has often both failed and succeeded in exploding the frozen material, with the usual and larger amounts of fulminate.

Nitro-glycerine is but little used in the liquid state. In this country the principal use made of it in this condition is for "torpedoing" oil-wells. But for most purposes, such as mining, quarrying, engineering work, etc., the liquid is very rarely taken, while powders of which it is an essential ingredient are very largely employed. There are very few instances in which the intense and local action of liquid nitro-glycerine is demanded, but the field for the application of nitro-glycerine powders, which are more powerful and violent than ordinary blasting powder, is very extensive. These powders are of many kinds and many names. They may be considered in two ways:

1st. As nitro-glycerine preparations whose power and usefulness depend essentially upon the proportion of that substance which they contain; and 2d, according to the absorbent with which the nitro-glycerine is mixed. The nitro-glycerine is the valuable ingredient of all these powders. The principal object of their manufacture is to present nitro-glycerine in a safer, more manageable and more

useful form. They are made containing from 5 to 75 per cent. of nitro-glycerine. The lowest grades—5 to 10 per cent.—stand nearly on a level with ordinary blasting powder in regard to force and the purposes for which they are used. The powders ranging from 20 to 75 per cent. include most of the so-called high explosives now so largely manufactured in this and other countries. Those containing from 30 to 60 per cent. are the most extensively used. Serviceable powders must retain their nitro-glycerine at all practical temperatures, but must not be too dry, as they are then more difficult to handle.

In some powders the vehicle or solid matter with which the nitro-glycerine is mixed is entirely inert (for example, the silicious earth from which Nobel's dynamite is made), while in others the absorbents are substances themselves capable of decomposition or action either directly or under the powerful influence exercised by the nitro-glycerine explosion, so that they affect the resultant force exerted. From this we have the classification adopted by some writers, of preparations having an inactive base and those having an active base; but this classification is not satisfactory, since it is the nitro-glycerine which is the essential and important constituent, and since the bases or vehicles used are not definite substances or mixtures; therefore, although the absorbent materials might be such as could form an active base, yet from the proportions or manner of admixture employed they may practically exert no influence. The character of the absorbent may exercise influence upon the explosion of the powder in several ways. It may be composed of bodies which will react and add to the gas generated and so to the force exerted. Its physical condition may be such as to contain the nitro-glycerine in a state favorable to its best use. Also upon it depends the density of the finished powder, a matter of considerable practical importance.

Of the powders with inert absorbent, Nobel's or Kieselguhr dynamite is a good example. Another is the Magnesia Powder, or Hercules No. 1, in which carbonate of magnesia is the absorbent. Still another is the Cellulose Dynamite of Trauzl, in which purified wood pulp is the vehicle. These are rich powders—70 to 80 per cent. of nitro-glycerine—and are but little used commercially. They are well adapted for military purposes and are so applied.

There are very many kinds or varieties of the lower grades of nitro-glycerine powders, but essentially they are much alike in general composition. As the quantity of nitro-glycerine to be taken up is

moderate, great absorptive capacity is not required. Usually the absorbent is a mixture composed of nitrate of soda with one or more combustible substances, such as sawdust, wood pulp, charcoal, coal, rosin, etc., etc. If in such a preparation the nitrate and the combustible are properly proportioned and thoroughly mixed, they take part in the reaction and add force to the result. But in many cases these materials are in such bad proportions, or so imperfectly mixed, that little or no valuable action can take place between them. In this connection it is not necessary to enter into detailed descriptions of particular powders to be found in the market. Those of this class are less valuable for military use than the richer ones, but of course can be made to serve quite well for torpedoes, etc., in case of need.

Explosive gelatine or gelatine dynamite is made by dissolving photographic gun-cotton in nitro-glycerine, or by mixing nitro-glycerine with collodion, removing the solvent by evaporation. Nitro-glycerine, with the aid of heat, dissolves soluble gun-cotton, forming a gelatinous mass of firmness varying with the amount of gun-cotton contained. At 160°–170° F. solution of the gun-cotton and gelatinization quickly take place. In explosive gelatine the nitro-glycerine is very strongly retained, not being given up under heat or pressure. Explosive gelatine is very insensitive to blows and is not easily exploded, requiring a very powerful fuse, and is not injured by water. Various substances may be mixed with the materials used in preparing this agent to form mixtures of different kinds. Camphor dissolves freely in nitro-glycerine, so that camphorated explosive gelatine can easily be made containing it in any desired proportion. This preparation is even more insensitive to blows or other mechanical action than the simple gelatine. When struck by a rifle bullet fired at a distance of 80 feet it does not explode. To determine its explosion, either strong confinement or a peculiarly powerful fuse is required. In many respects explosive gelatine (particularly the camphorated variety) has special advantages for military purposes. It is considerably stronger than dynamite (75 per cent.) or compressed gun-cotton, and it is very free from liability to accident or injury in use or transportation. On the other hand its stability is a matter of question. Instances of its decomposition on keeping or after long exposure to moderate temperatures have been observed. It is probable that this difficulty may be removed. Soluble gun-cotton is apt to contain traces of free acid and to vary greatly in composition. Special care must be taken in making the gun-cotton to insure uniformity and

complete purification. If this tendency is overcome it is probable that explosive gelatine may be valuable for military purposes.

Some of the instances of decomposition of explosive gelatine have been cited in these Proceedings, Vol. VII, p. 486. In a prefatory note to Addendum I. of Gen. Abbot's report upon Submarine Mines, he states that "all the samples of the explosive gelatine remaining on hand after the trials detailed in the report have undergone spontaneous decomposition, separating into cellulose and free nitro-glycerine, with the copious evolution of nitrous fumes. This change occurred during the winter and spring of the current year (1881-1882), and was not caused by any exposure to high temperatures while in store."

A case of spontaneous decomposition of a small amount stored, freely exposed to air, in a dry room of even temperature, has occurred under my own observation. The camphorated explosive gelatine was wrapped in paraffine paper and then in light-brown wrapping paper. After something more than one year's exposure it was found in the early winter to be giving off nitrous fumes which had stained the wrapping paper, and to have shrunk considerably in volume, and that the outside of the paper was covered with congeries of fine crystals, while the odor of camphor was very strong. It was immediately put in a vessel of water, and after a short time the mass, which was friable, disintegrated. The camphor odor soon disappeared and the water became of a straw color, gave a strong acid reaction, and showed a slight trace of nitrous acid, but no nitric acid. On evaporation of the filtered liquid, oxalic acid crystallized out in quantity, and on evaporation of the mother liquid farther, on the water bath, a sugar-like mass was obtained which gave the glucose reaction with Fehling's solution.

The paraffine was regained unchanged and the paper was recovered, but in a flocculent condition, and with the color bleached from the brown. Careful search failed to reveal the presence of glycerine, nitro-glycerine or gun-cotton. The cellulose from the gun-cotton could not well be detected (if it existed) in the presence of so much flocculent cellulose from the paper.

The results obtained by De Luca in his "Researches on the Spontaneous Decomposition of Gun-Cotton," *Comptes Rendus*, 59, 487, September 12, 1847, are interesting in this connection. Gun-

cotton decomposes most rapidly when heated to 50° on a water bath, next by sunlight, more slowly by diffused light, and very slowly in darkness. The gun-cotton first shrinks to $\frac{1}{10}$ of its original volume, next it begins to become gum-like and sticky, then it swells; during all these phases it gives off nitrous fumes, but especially during the last. For the fourth phase the gas ceases to be evolved, and the mass becomes brittle and of a light color like sugar. The products are nitrous compounds with formic and acetic acids in the state of a gas, and an amorphous, porous, sugar-like body, almost entirely soluble in water and containing an abundance of glucose, gummy matter, oxalic acid, a small quantity of formic acid, and a new acid, of which he obtained the lead and silver salts for later examination. From 100 grams of gun-cotton he obtained about 14 grams of glucose.-

As regards the decomposition of nitro-glycerine, A. Brull states, on page 26 of his "Études sur la Nitro-glycérine" (Paris, 1875), that concentrated sulphuric acid, cencentrated nitric acid and concentrated soda solution attack nitro-glycerine even in the cold and provoke a progressive decomposition. Nitro-glycerine, which retains a trace of free acid, is not stable. In general, the decomposition is extremely slow and tranquil. It disengages at first nitrous vapors, the liquid taking a greenish color. Then there is formed nitrogen and carbon dioxides and crystals of oxalic acid, and after some months the entire mass is transformed into a greenish, gelatinous matter composed of oxalic acid, water and ammonia. Sometimes, if the temperature is high, as when heated by the sun, the decomposition is more active, but it very rarely causes an explosion.

Major W. McClintock, R. A., has been making a series of experiments with small shot in order to test the accuracy of various statements as to the strength of Schultze powder (sawdust powder) and E. C. powder (granulated gun-cotton), and also to determine the velocity when black gunpowder was used, since little was known concerning this. The Boulengé chronograph was used for measuring the observed velocities and Bashforth's tables were employed for calculating the remainder. All the cartridges used were bought from the same tradesmen, who obtained them direct from the factory, and although the method of loading was identical in all, and the powder (in those charged with gunpowder) was supposed not to vary in quality, it was found that no two boxes gave similar results. The cartridges were then examined, and it was almost invariably found that

the amount of powder was deficient and the weight of shot in excess. This deficiency of powder amounted in one case to 8 grains, and the excess of shot in the same cartridge to 64 grains. The powder too was found to vary in appearance and size of grain, and when some cartridges from each box were stripped and carefully reloaded with correctly weighed charges, the muzzle velocities showed that the powder varied very much in strength. These experiments show that the mean velocity obtained with *unweighed* charges should not be considered as proof of the quality of the cartridges, because one or two rounds which have a heavy powder, or light shot charge, may unduly raise the average. Taking weighed charges of 492 grains (= 1¼ oz.) of shot, 82 grains (= 3 drams) of gunpowder, and from 45 to 47 grains of Schultze or E. C. powder, it was found that the average velocity of the last two was over 100 f. s. greater than gunpowder. The determined velocities of even the carefully made-up charges showed considerable variations, but source of error exists in the use of small shot, owing to the fact that the quickest pellets of the charge need not always cut the wires but may pass through the meshes. Major McClintock thinks that his experiments with the Schultze and E. C. powders were so few that it would be premature to form any decided opinions concerning them at present, but he states that these explosives possess great strength (sometimes too great), make little smoke and cause slight fouling, but the velocities they give are not regular. These experiments are given very much in detail, with copious tables, and are accompanied by an account of researches made to determine how the boring of the gun-barrels affects the muzzle velocity.—(*Proc. Roy. Artil. Inst.* **12**, 332, Aug. 1883.)

In these notes, Vol. VIII, p. 444, an abstract of the testimony in the case of the Atlantic Giant Powder Co. against the Dittmar Co. is given. Recently some of the papers in the suits of the same company against George A. Goodyear, George W. Townsend, Michael Brady, and the Neptune Powder Co. have come into our hands. The compositions of the various explosives which the Atlantic Giant Powder Co. regarded as infringements of their patents were as follows:

Vulcan Powder.

Nitro-glycerine	32.60 per cent.
Nitrate of soda	49.46
Charcoal	9.63
Sulphur	8.31

Neptune Powder.

Nitro-glycerine	32.66 per cent.
Nitrate of soda	45.04
Charcoal	17.44
Sulphur	4.86
Ash	0.94

Miners' Powder Company Dynamite.

Nitro-glycerine	32.91 per cent.
Nitrate of soda	49.88
Charcoal, wood and partially charred wood	17.21
Ash	1.18

Brady's Dynamite or Vulcan Powder.

Nitro-glycerine	33.00 per cent.
Nitrate of soda	50.00
Charcoal	10.00
Sulphur	7.00

It will be observed that all these powders are practically dynamites in which gunpowder is used in place of infusorial earth as the absorbent. In regard to the powder made by Michael Brady, Thomas Varney, a manufacturer of nitro-glycerine, dynamite, &c., testifies that it "belongs to a class which is now quite large and known as high explosive powder. Some of their names are Giant Powder, Mica Powder, Vulcan Powder, Jupiter Powder, Neptune Powder, Thunderbolt Powder, Hercules Powder, Titan Powder, Rend-Rock Powder, Vigorite Powder, Lithofracteur Dualin.

"They are made by mixing nitro-glycerine with a dry pulverized substance, or mixture of substances such as have the capacity of taking up and holding a sufficient proportion of nitro-glycerine by absorption to make the mixture an effective explosive, and yet without being in such excess as to separate from the mass by leakage or compression, and at the same time the absorbent solids employed being such as will not chemically injure the proper explosive quality of the nitro-glycerine, and such as will render the mass practically inexplodible by concussions which ordinarily occur in handling and transportation. The solid ingredients, to-wit, the nitrate of soda, charcoal and sulphur, are first ground or otherwise pulverized, and dried if necessary. The nitro-glycerine is then carefully mixed with

them, so as to make a mass as nearly homogeneous as practicable, and the powder is then packed for market.

"In the manufacture of Vulcan powder there is a combination of nitro-glycerine with absorbent substances which are the equivalents of infusorial earth; and this combination constitutes an explosive compound, which has all the properties and qualities of the compound made by combining nitro-glycerine with infusorial earth in making dynamite or Giant powder, or with mica scales in making Mica powder, or with mealed gunpowder in making Vulcan powder.

"In the first place, each of the materials used as absorbents in the Vulcan powder is solid. In the next place they are all free from any quality which will decompose, destroy or injure the nitro-glycerine. They are capable of pulverization. They are also dry, or may be made so. When pulverized each of them alone, or all of them in the proportions actually used, or in any other proportions, they will absorb and hold nitro-glycerine to the extent required by the patent sued upon, to-wit, enough to make an explosive powder without rendering the powder leaky, and without any explosive aid from the absorbents themselves.

"Dry pulverized nitrate of soda will thus hold 30 per cent. of nitro-glycerine, charcoal 45 per cent., sulphur 30 per cent. (all these are explosive compounds), and when combined, as in Vulcan powder, they will thus hold 33 per cent."

After asserting that the absorbent of the Vulcan powder is similar to the infusorial earth in converting the liquid nitro-glycerine into the solid form, he adds: "The Vulcan powder absorbent, like that of the Neptune and Vigorite absorbents, has one quality not possessed by infusorial earth, to-wit, combustibility; but this quality does not affect the powder as dynamite. Its only effect is to allow the absorbent to be burned by the heat of the exploding nitro-glycerine, thus adding gas and force to the explosion. Vulcan powder is no more combustible than dynamite of infusorial earth; in fact, not as much so—that is, if an equal quantity of the two be set on fire, the Vulcan powder will burn the longest. Vulcan powder is practically as safe against concussion as infusorial earth dynamite.

"This particular class of powders, with combustible absorbents, has been made and sold by the complainant since the commencement of its business, which was in October, 1871. It had previously been made and sold by Alfred Nobel & Co. and by the Giant Powder Company, and by no other person or party prior to its use by them,

to the best of my knowledge and belief. It has always been made and sold by the two Giant Powder companies, under the name Giant Powder No. 2, and labelled as patented under the original dynamite patent of May 26, 1868, and its reissues. Nobel & Co. have always made and sold it as Dynamite No. 2. The two Giant Powder companies have made and sold more of No. 2 than of No. 1—meaning by No. 1 infusorial earth dynamite, or Giant powder. The nitrates of our No. 2 have always been those of potash or soda. It has been the same with Vulcan powder. Our carbons have been rosin, bituminous coal, pulverized wood or sawdust. These have been our favorite materials, but we have experimented with and tried in practice for a longer or shorter time many other things. As to charcoal, one of the earliest things tried, we found it not so good as several other things. As to sulphur, we long ago abandoned its use. In gunpowder to be burned by itself it is useful as facilitating ignition; but when combined with nitro-glycerine it is not needed for this purpose, as the absorbent is readily fired by the exploding nitro-glycerine. For absorbing it is no better than the nitrate, and not as good as charcoal, or any of the carbons or hydrocarbons used in absorbents. In other words, the sulphur in Vulcan powder is useless for any purpose except as an absorbent, and for that purpose would be better replaced by the same amount of nitrate and carbonaceous matter.

"The fine pulverization of the Vulcan absorbent is mainly for the purpose of increasing its absorbent capacity. Ordinary well-grained gunpowder will not safely take and hold over ten per cent. of nitro-glycerine; but in the form of meal powder, its state before being grained, it will take and safely hold 45 to 50 per cent. The pulverization may be considered as having another advantage for purposes of absorbents, to-wit, the nitro-glycerine will be more intimately distributed in fine than in coarse materials, and the heat of the exploding oil will take effect quicker, and thus add force to the explosion.

"When Vulcan powder is exploded in practical use an exploder is always used. This exploder, by the force of its explosion, explodes the nitro-glycerine contained in the powder precisely as the nitro-glycerine is exploded in No. 1 Dynamite. The explosion of the nitro-glycerine in No. 1 does not affect the infusorial earth, which is incombustible, but in No. 2 Neptune, Vigorite, Vulcan, &c., the nitro-glycerine explosion produces high heat, which burns up the combustible absorbent. Any pulverized combustible would be consumed in like manner. Sawdust, charcoal, dried paper pulp, rosin, paraffine,

pitch and other carbons or hydrocarbons which have been used in making No. 2 are all completely consumed, just as is the Vulcan absorbent."

Robert J. Howe, a dealer in powder and various explosives, and formerly foreman of the Laflin Powder Company's mills, testified for the defendants in the Neptune Powder Company case as follows:

"Neptune powder compound, before adding nitro-glycerine, is in the form of powder dust, and is an explosive in itself. If ten per cent., or any greater proportion of nitro-glycerine which it can retain, is added to it, the resulting compound is explosive, while infusorial earth must contain over thirty per cent. of nitro-glycerine to explode at all, and a much larger proportion to make an effective explosive. Grained gunpowder, mealed gunpowder, gunpowder dust or Neptune compound will not take up and retain more than about thirty per cent. Difference in temperature makes a difference in the retentive power of the substances. They will retain more in cold weather than in warm. My experience teaches me that about thirty per cent. of nitro-glycerine is the quantity they can be relied upon in practice to retain. Dry pulverized nitrate of soda will not take up and retain thirty per cent. of nitro-glycerine, but only about fifteen per cent. It might be made to retain, under certain conditions of temperature, twenty per cent., but when thirty per cent. is added to it it slowly trickles from it, and upon being squeezed in the hand it is discharged between the fingers.

"A mixture of 70 parts of either infusorial earth, charcoal or sawdust with 30 parts of nitro-glycerine is inexplosive, yet either of the following mixtures are explosive—

Nitrate of soda	75	or 40	parts.
Charcoal	10		"
Nitro-glycerine	15	15	"
Sawdust		20	"

Also these are explosive—

Gunpowder dust	90	parts.
Neptune compound	90	"
Nitro-glycerine	10	10 "

"The nitro-glycerine does receive explosive aid from the Neptune compound, from gunpowder, from gunpowder dust and from a mixture of sawdust and nitrate of soda. It is a well-known fact that

gunpowder is more effective when exploded by percussion caps than by simple fuse. Some consumers (contractors) always use percussion caps for that purpose. For the same reason, caps are better to explode Neptune powder, but Neptune powder is largely used by some parties and exploded (without cap) by fuse alone. In such use the powder of the Neptune powder explodes the nitro-glycerine of the Neptune powder in the same manner as indicated in the patent to Nobel, No. 50,617, filed 10th May, 1865."

Dr. Henry Morton, President of the Stevens Institute, testified "That while at North Adams, in December, 1875, I mixed 52 parts of nitro-glycerine with 48 parts of infusorial earth sent me by the complainants, and made this into a cartridge of the usual form, and inserted in this an 'exploder' or cap containing 16 grains of fulminating mercury. When this was fired in the usual way the cartridge did not explode. I then placed another 'exploder' or cap containing 22 grains of the fulminate in the cartridge, and enclosed the whole in a short wrought-iron tube, tamping the ends with sand. On firing this 'exploder' the iron tube was split open by the force of its explosion, but the mixture of infusorial earth and nitro-glycerine remained unaffected as before. I am, therefore, quite certain that a mixture of infusorial earth and nitro-glycerine in the proportions found by Dr. Hayes between the gunpowder and nitro-glycerine in the explosive compound* of defendants, would be totally inexplodible."

Prof. Morton then goes on to show that using various devices for increasing the explosive force of gunpowder is no new thing and cites the following: "In the *Chemical News*, London, July 6, 1866, on p. 16, he finds as follows: Some experiments were in the first instance made with gunpowder the grains of which had been saturated with nitro-glycerine. This powder burned much as usual, but with a brighter flame in open air. When confined in shells or blast holes, greater effects were, however, produced with it than with ordinary gunpowder; its destructive action is described as having been from three to six times greater than that of powder.

"The same account is published in the *Proceedings of the Royal Institution*, Vol. IV, p. 621, London, 1866. It is also published in the Journal of the Franklin Institute, Philadelphia, 1866, Vol. 52, p. 275.

"This deponent further says, that the increasing of the explosive force of gunpowder by the admixture of various bodies with it has

*Neptune powder.

been from time to time practiced from the early part of this century; thus, in the *Encyclopædia Britannica*, Edinburgh, 1815, is found an account of experiments made by Count Rumford. He used oil of turpentine, quicksilver, salt of tartar, sal ammoniac and brass filings, with this object. In *Cutbush's Pyrotechny*, Philadelphia, 1825, p. 140, we find: Quicklime is said to increase the force of powder. Dr. Baine says that three ounces of pulverized quicklime being added to one pound of gunpowder, its force will be augmented one-third. M. Vergnaud, in a work on fulminating powders in 1846, asserts that certain rifle powder consisted of gunpowder mixed with fulminate of mercury. In the *Mechanics Magazine*, London, 1825, Vol. 3, p. 275, we find a description of experiments with powder mixed with oil, which showed an increase of effect. In *Ure's Dictionary*, New York, 1853, p. 174, we find admixture of sawdust with gunpowder recommended as increasing its explosive force. In the *London Artizan* of 1862 we have a description of Mr. Bennet's improved blasting powder, which consisted of a mixture in which lime was added to the usual ingredient of gunpowder. In the *American Repertory*, New York, 1841, Mr. Mayer proposes admixture of rosin with gunpowder to increase its effect in blasting."

The injunctions against the manufacturers of Neptune and Vulcan powders were granted. The value of this monopoly may be shown as follows: It is claimed that with proper exploders a dynamite composed of 30 per cent. nitro-glycerine and 70 per cent. meal powder will do as much work as a dynamite composed of 75 per cent. of nitro-glycerine and 25 per cent. of infusorial silica. The difference in cost may be estimated as follows:

Vulcan Powder.

70 lbs. of meal powder, @ .04	$ 2.80
30 " nitro-glycerine, @ .40	12.00
100 lbs. of powder cost	$14.80

Dynamite No. 1.

25 lbs. of infusorial silica, @ .03	.75
75 " nitro-glycerine, @ .40	30.00
100 lbs. of dynamite cost	$30.75

In a previous suit Judge Blatchford issued an injunction against the manufacture of the following powders:

	No. 1.	No. 2.
Nitro-glycerine	67.64	27.86
Cellulose (paper stock)	16.82 (sawdust and charcoal)	5.59
Nitrate of soda	15.54	66.55

The Popular Science News, James R. Nichols, M. D., editor, **17**, 53, May 1883, contains an editorial article entitled, "What is Dynamite?" from which we extract the following as being a good example of popular science. Referring to the recent difficulties in England, Russia, Spain and elsewhere in Europe, it says: "In dynamite we have a pasty black mass, almost perfectly safe to handle, of which enough can be carried in a side pocket to destroy the lives of a hundred men, if favorably situated, or shatter a building nearly as effectively as could be done with half a barrel of gunpowder placed under it.

"What is dynamite? How is it manufactured? We are fully prepared to answer these questions, as we manufactured the first nitro-glycerine ever made in the United States, nearly twenty years ago, and have had some experiences with it not pleasant to recall. Dynamite is simply nitro-glycerine mixed with an adulterant to render it safe to transport. The added ingredient is usually a fine earth of great absorbent capacity. It has been found that the best kind is the earth which good housewives use to polish their silver with, properly called *infusorial* earth, because it is made up of the fossil remains of minute organisms. Dynamite, then, is a mixture of innocent polishing powder and sweet, bland glycerine, after it has been acted upon by nitric acid. There is nothing apparently very frightful in this mixture. We can eat glycerine on our puddings and griddle-cakes and grow fat upon it; and a box of silver polish in the house is as harmless as a cake of soap.

"In what has been stated, a strange law of chemical combination comes into view, a law by which a vast change is produced in innocent bodies by a slight disturbance of their molecular constitution. We disturb the molecular constitution of glycerine by subjecting it to the action of nitric acid, by which nitrogen becomes a constituent of the body, and its whole chemical nature and relationship are changed.

"The dull, stupid nitrogen which exists so abundantly in the air, and which we breathe into our lungs every moment, day and night, becomes the agent which confers upon glycerine the most terrific powers possessed by any agent, save two, known to man. Does not this fact teach an impressive lesson as to the mystery of the forces of nature, and of man's capability of bringing them into action, and we may say, into subjection? If such facts do not cause a feeling of respect for chemical science, it is difficult to conceive of any that will.

"In the manufacture of nitro-glycerine we simply mix with pure glycerine a certain proportion of sulphuric and nitric acids and stir the mixture until the reactions occur, which is in about twenty minutes. The vessels must be placed in freezing mixtures, for if at any time the temperature rises above 32° F. decomposition occurs, and if there is no explosion the whole mass goes off in a vast cloud of nitrous acid vapors which are troublesome and dangerous.

"We never ventured to act upon more than one hundred grains of glycerine at a time, and with this small amount the danger was great and accidents were not a few.

"Our method was to arrange upon a shelf, in a refrigerating mixture, twelve beaker glasses, each containing one hundred grains of glycerine, and into each of them the mixed acids were slowly allowed to enter, the thermometer being anxiously watched all the time. If the heat from the reactions rose above 32° in any glass, away would go the contents, filling the laboratory so densely with red fumes that no object could be seen six feet distant.

"It was regarded as a successful experiment if we saved four glasses out of the dozen. Whilst at present the methods of production are not different, the apparatus and appliances are greatly improved. It must be remembered that we were pioneers in the dangerous manufacture, and but little of the product was needed in medicine and the arts. Now the consumption is enormous, and large manufactories are established in many sections of the country. The United States government chemists make the best nitro-glycerine at the laboratory at Newport, Rhode Island. It is used largely for filling torpedoes.

"In what has been said we have endeavored to afford a popular view of the chemistry of dynamite. It does not explode at the touch of fire, as does gunpowder, but it must have brought to bear upon it, or in contact with it, another explosive agent, a *fulminate*. A fulminate of mercury is better than a fulminate of silver, for the *rhythm* of

its detonation is more in accord with that of dynamite. Dynamite *detonates*, and does not explode as does gunpowder. Its action is so much quicker than the movement of air that it strikes against a column of air with the same force as a hammer falling upon a blacksmith's anvil."

The following books may be of interest to students of explosives:

Die Grundsätze der Thermochemie. Dr. Hans Jahn. Vienna, 1882. Alfred Holder, 8vo, 238 pp.

Thermochemische Untersuchungen. Julius Thomsen. Vol. I. Neutralization und verwandte Phenomena, 449 pp. Vol. II. Metalloide, 506 pp. Leipzig, 1882. J. A. Barth.

Lehr- und Handbuch der Thermochemie. Dr. Alex. Naumann. Brunswick, 1882, F. Vieweg und Sohn. 606 pp.

The Explosive Art, 1875, and the Orders in Council of April 20, 1883, their Prejudicial Effect on Mining and Quarrying, and the Encouragement they give to Fenians. London, 1883, A. P. Blundell & Co.

NAVAL INSTITUTE, ANNAPOLIS, MD.

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SUGGESTIONS IN FAVOR OF MORE PRACTICAL AND EFFICIENT SERVICE EXERCISES.

BY LIEUTENANT NATHAN SARGENT, U. S. N.

The signs of the times, as shown by the recommendations of the President's Message, the Report of the Secretary of the Navy, the leading articles of prominent newspapers, and the late resolutions of the Union League Club of New York and Chamber of Commerce of San Francisco, go to prove that the consensus of opinion throughout the country is in favor of a decided increase of the matériel of the Navy, and that we may soon expect to have the service supplied with a fleet of modern and effective vessels.

These vessels, if not formidable, will at least be excellent ones of their type; and being armed with guns of the most approved pattern and highest power, will not be handicapped by either the antiquated smoothbore, or the makeshift converted rifle, to which we have so long been accustomed.

This, of course, is a matter of great congratulation to the naval officer; who, in hailing the dawn of a new era, cannot help remembering how for many years he has been mortified by being obliged to cruise in foreign waters, in vessels of a type some twenty years behind the age, and whose ingenuity has often been put to the test in attempting to answer the questions propounded by foreigners and foreign officials, who could not understand the anomaly of the richest country in the world having the weakest navy, with types of ships and guns long since abandoned by the principal maritime powers.

But, however satisfactory may be our new ships, and however powerful our new guns, their effectiveness will be almost *nil*, unless we have an efficient, well trained, and intelligent personnel to man them. For this, the responsibility rests directly with the officers of the service.

For many years past, whenever the lamentable state of our navy has been mentioned, a strong contrast has at once been drawn between ships and personnel, and the latter has always been declared equal to that of any other service. So it may be, so far as raw material is concerned; but, if untrained, and unacquainted with the resources, requirements, and methods of modern naval warfare, it will be substantially useless in any conflict, even if opposed to an enemy far inferior in natural qualifications.

Our service has a glorious record in the past, but its record is due largely to the fact that the careful training its men had received rendered them much superior to those with whom they came in conflict. In the French war and in the war of 1812 our successes were owing, not only to the superiority of our ships (as urged by the enemy), but also to the fact that our adversaries paid little attention to gunnery in exercising their crews; our men, on the contrary, had been instructed with the utmost care, and particular consideration had been given to their target practice and manner of firing in a seaway. The good results of this training were shown by the favorable issue of many actions, in which we had to contend, not only with equal force and valor, but with the prestige established by years of maritime supremacy. The most noted of our reverses in the war of 1812 was when the unfortunate Chesapeake, with an untrained crew, was opposed to a vessel commanded by an officer who, in a commission of over four years, had been untiring in his endeavors to improve the gunnery of his men.

With such an experience to look back upon, one might imagine that the present day would find our personnel at the highest point of excellence, with a training far in advance of that of foreign navies, and ready for any emergency of sudden war. That such is not the case is due to the fact that a prevailing characteristic of our service is extreme conservatism. Any proposed change from the existing order of things, in whatever manner, or however sensible and beneficial, raises a storm of objection and disapproval; the more requisite the change, and the more apparent to thinking minds its necessity, the more decided seem its opponents, and the more strenuous their efforts to prevent its accomplishment. This tendency blocks the way to any improvement in the training of our crews, and explains why there has been little or no alteration in the usual drills and exercises for the last twenty years.

But, the ultimate object of a naval force being *readiness for* WAR,

we cannot afford to stand still while other nations are advancing, and it behooves us, the officers of the Navy, to see that its personnel is kept up to the mark of modern effectiveness, and is made worthy of its traditions and reputation.

How far behind the times we are may be seen by an inspection of any of our fleet or ship routines, showing what drills and exercises are considered necessary. Sail and spar drill, general and fire quarters, and an occasional boat exercise, constitute the major part of all requirements; while at rare intervals a landing party is organized, and the men are sent on shore in their mustering clothes to go through a dress-parade, which, as a military ceremonial is generally a failure, and as a land evolution is of no utility whatever as a preparation for service.

Some three years ago the writer witnessed the landing of a large naval force at Fortress Monroe. For weeks the papers had been heralding a grand naval review, and the New York dailies and illustrated journals had sent their correspondents and artists to describe and depict the interesting manœuvres that were anticipated. The North Atlantic and Training Squadrons had rendezvoused in Hampton Roads, the Secretary of the Navy and other high officials were present, and there was nothing to prevent a series of exercises of great utility and interest. But what was the result? There were some fleet and ship drills with sails and great guns, but little attention was paid to them, the main object of interest being the proposed landing party of blue-jackets and marines. At last a signal was made for the force to embark, and soon after, for the squadrons of boats to form opposite the beach. There was no attempt to simulate the covering of the party by a fire from either launches or vessels, during the full hour consumed in forming the boats into line; and the presence of the most insignificant number of an enemy on the dunes of the beach would have been sufficient to effectually prevent all chances of landing. The same lack of any resemblance to real service was shown in the landing itself. There was a general race and scramble for the beach, the men jumped out, pulled up their boats, and formed into battalions; no effort being made to throw out skirmishers, nor to guard against surprise by any of the precautions that would necessarily be taken in time of war. The shore organization effected, the party was marched into the fort, and were drilled at forming and changing front *in mass*, and in having a brigade dress-parade and review.

Now, of what use to any one, officer or man, was such an exercise as this, and what experience could be gained from it, other than the negative one of teaching us to avoid all of its defective details?

All recent naval expeditions and operations have shown the necessity of having an effective landing force, well organized and capable of rendering good service on shore, by being properly equipped and instructed in some system of tactics adapted to the duties likely to be required of it.

Every one will acknowledge that an exercise of this description should be one calculated to make both officers and men fully conversant with the dangers and difficulties likely to be encountered in actual service. The autumn manœuvres of the German and French armies do not consist of reviews and dress-parades, but of operations extending over several days, and embracing all the discomforts and hardships, and calling for all the skill in tactics and strategy, necessary to actual campaigning. Again, men are no longer fought in masses; the best military authorities recognize and announce the fact that open order is the formation of the future, yet the skirmish drill is usually the last thing taught the sailor. If, perchance, a progressive divisional officer desires to drill his men as skirmishers, he is likely to have the greatest difficulty in obtaining the requisite permission from the conservative first lieutenant, and is perhaps looked on by others as a *rara avis*, holding unusual or ridiculous ideas, or as one who is anxious to pose in the role of a reformer. But the purpose of our drills is not only to give the sailor employment and exercise, but especially to fit him for such service as he may at any time be called upon to perform, whether on board ship, in torpedo boats, or on shore.

The object of each system of instruction should be to impart the knowledge that will earliest bring the seaman to the desired state of proficiency. What has recently been said by Lord Wolseley in reference to the English soldier may apply with equal force to the sailor. He remarks: "As nowadays you have only a limited time to teach him in, you ought to devote it exclusively to instruction in useful things; and in teaching him useful things you will discipline his mind and body quite as well as if you taught him complicated manœuvres, which are very pretty to look at, but utterly impracticable in the field."

The aim of modern instruction is *utility*, and the best and most expeditious way of acquiring that utility is what is needed afloat as well

as on shore. The man-of-war's-man of to-day is a very different being from the sailor of fifty years ago, and is a person from whom a much greater degree of intelligence is expected and required; more attention should therefore be given to his instruction as necessitated by the great changes and improvements in great guns, machine guns, magazine guns, small arms, and torpedoes. The probability of having to use or to contend with any or all of these new inventions should necessarily be considered, and our drills should be more in conformity with such requirements. Should this change take place we might soon miss the mediæval cry of "boarders away!" and the sight of the picked men of the ship rushing to the most exposed parts of the upper deck, and with a mighty cheer swarming up on the bulwarks and cleaving the air with their cutlasses. How many minutes, nay, seconds, would it require an enemy, with the modern complement of Hotchkiss, Nordenfeldt, Gardner, or Gatling guns, to sweep them away as so much chaff? Boarders may still be needed in cases of ramming, but they must be manœuvred very differently from the manner of the past.

The daily drills might, with propriety, be carried on in a manner more consistent with the increased intelligence of our men, and the divisional officer should act more in the capacity of an instructor, and less in that of a simple drill-master. Great attention should be paid to target practice with great guns, machine guns and small arms;* the battery should be frequently laid for concentrated firing, both by hand and by electrical action; movable targets should be improvised, and the vessel should be under way when firing at them; the effect of drift and of wind blowing across the line of fire should be explained, not only to the gun captains, but also to others who may be called upon to take their place; the manipulation of fuses should be familiar to all; the use of machine guns on deck and aloft, and the defence of tops against small-arm fire, are part of the requirements of the future; while readiness for ramming and for launching torpedoes in action are preparations for emergencies likely to occur with even the weakest wooden vessel.

The subject of torpedoes has become a very important one, and likely to be of momentous interest in the naval warfare of the future. The truism of this statement being universally acknowledged, one might imagine that we should find both officers and men fully in-

* The English have an effective movable small-arm target, representing a man running from cover to cover.

structed in every detail of the subject, and that frequent drills with and against torpedoes would be held. Unfortunately, even in this important particular we do not seem disposed to keep up with the times. To be sure, there is a class of officers every summer at the Torpedo School for a short course of three months; but the knowledge obtained in that time is necessarily superficial, and so rarely brought into requisition on board ship that the greater part of it is soon forgotten.

As for the men, they receive no instruction whatever, and the only chance they ever have of acquiring any information on the subject is when, very rarely, a launch is sent out to explode a spar torpedo, usually as a test of the electrical machine, and not as a movement against an imaginary enemy.* While other nations (as the English in their fleet exercises last July, in Bantry Bay, and the Italians, in their manœuvres last November) are accustoming their men to the different kinds of torpedoes, mines and countermines, and to the manipulation of them; to torpedo attack and defence, by day and by night, at anchor and under way; to the obstructing and clearing of harbors and channel ways; to the use of the electric search light, torpedo nettings, machine guns and other means of resisting attacks from swift torpedo boats, we are standing idle, and are doing little or nothing to render our seamen conversant with such emergencies, or to impart to them the requisite knowledge for prompt and proper action in case of such necessity. At the present time, the smallest and most insignificant navies are being supplied with English torpedo boats, of the most approved models and greatest speed; yet we, with our ostrich policy, do not even attempt to anticipate the manner of defending ourselves, in case we should suddenly be drawn into war with any of them. If the effectiveness of the service be not a sufficient consideration, we

*The British lords of the admiralty, considering it desirable that instruction in the torpedo school should form an essential portion of the course for all seamen gunners, have made the following arrangements which are to take effect from November 16: "Every seaman gunner on requalifying, and every seaman in future desirous of qualifying, in a gunnery school, will also be required to go through a course of torpedo instruction in a torpedo school before being available for draft for service afloat. The gunnery course for qualifying and requalifying in the gunnery ship is to remain as at present. The time under torpedo instruction, including examination, will be sixty working days."

The writer has known of but one ship in our service where the men received any special torpedo instruction, and in that case the officers of the vessel were severely criticized for "teaching their men too much."

might be guided by a certain old and well-established aphorism, and on the score of self-preservation take the needed measures of preparation.

A night attack from twenty-knot torpedo boats, with all the moral effect of uncertainty and dread, even with the most approved means of defence, will be the greatest strain upon their nerve and discipline that a ship's company may have to encounter; but a proper knowledge of what has been done under similar circumstances, and of the good result of quick and concerted action, will go far towards preventing the panic to be feared at such a moment, and will result in the adoption of decisive and effective measures. An occasional exercise at preparation for such an attack would not only render our officers and men conversant with all the circumstances of the case, but many points which otherwise would not have been foreseen might be suggested by the actual occurrences, if part of the crew should represent an attacking force. Exercises of this kind would give to every one a certain amount of knowledge and experience, which at some future moment might be of great benefit either in attacking an enemy or in acting in our own defence.

With other considerations of practicable and practical readiness for war, opportunities should be given officers to perfect themselves in the management of the vessel to which they are attached, by experiments calculated to give them a just idea of her evolutive qualities; of the effect of different positions of the helm, both in going ahead and astern, and of the difference caused by the trim of the ship or by her heeling; of her turning powers at different speed, her tactical diameter, etc., etc. The effect of concentrated and other firing under all circumstances of heel, etc., and in all weathers should be carefully noted for future reference. More frequent fleet sailing and the use of naval tactics, both with steam launches and with the vessels of the squadron, should be carried on, not only for instruction in the tactics, but also as a means of acquainting officers with the steering and other qualities of their ships. The mere retaining of position on a dark night calls for an extreme degree of care and watchfulness, and is in itself a valuable experience; as an English authority has recently remarked,* "It can only be understood by those who have seen the confusion caused by two or three vessels losing their position, or by those who know the watchfulness and the precautions called for by a manœuvre necessitating a great change of course."

*Captain R. H. Harris, in Journal United Service Institution.

The attention of officers could also with propriety be given to a consideration of a tactical line of policy, in case of possible war with the country in whose waters they happen to be serving, and to the strategical advantages of certain points within their limits. A habit of such observation and thought might stand them in good stead in the future, and be of great advantage not only to the service, but also to themselves.

These few suggestions are offered with all due diffidence, not so much with any confidence in their own utility, as in the hope that their discussion may call forth others of real value. The conservative element already mentioned would oppose a change of any kind, but most of us will acknowledge that we cannot go on in the methods of twenty years ago, and will agree that with our new ships we should have a personnel equal in all respects to those of other nations. Our men are inferior to none in intelligence, but their intelligence will be of no avail without the proper instruction and exercises in accordance with modern inventions and practices.

All that the writer advocates is that our drills shall conform to the requirements of modern warfare, and he feels assured that every one will agree with him as to the propriety (although they may not be of the same mind as to the manner) of maintaining our efficiency at the highest possible standard, so that all foreign services may recognize the fact that our officers and men are thoroughly keeping pace with the ideas and inventions of the time, and are prepared to do the utmost possible with the means at their command.

NAVAL INSTITUTE, WASHINGTON BRANCH.

APRIL 19, 1883.

PROFESSOR J. RUSSELL SOLEY, U. S. N., in the Chair.

DISCUSSION.

PRIZE ESSAY, 1883. BY LIEUT. CARLOS G. CALKINS, U. S. N.

HOW MAY THE SPHERE OF USEFULNESS OF NAVAL OFFICERS BE EXTENDED IN TIME OF PEACE WITH ADVANTAGE TO THE COUNTRY AND THE NAVAL SERVICE?

THE CHAIRMAN.—Before proceeding with the discussion of the admirable essay of Lieut. Calkins, to which we had the pleasure of listening three weeks ago, it may be worth while to summarize its leading points.

The essay starts out with a statement which underlies the discussion of the whole subject, namely, that the Navy can never obtain the support which is necessary to prepare it for the highest usefulness in time of war, until the importance of its services in time of peace is admitted. This main fact lies at the root of the whole question. It shows the reason why this subject was presented for discussion as the subject for a prize essay. It may be suggested that the object of a navy is to fight; that the true purpose, end, and aim of the work of the naval profession is war. How is it then that the question arises as to what work should be done specifically by naval officers in time of peace, other than that of preparing themselves for war? The answer lies in the statement of Lieut. Calkins, which is so well set forth at the outset. In order to reach its highest activity during war, the Navy requires support and encouragement from the community and from the country. At present the Navy does not get that support; and it can be obtained only when the community is forced to see that the services of the Navy in time of war and in time of peace, at all times in fact, are of the highest value to the country.

In discussing the general question, the writer lays down three broad principles in regard to any kind of work that should be done by naval officers in time of peace. The first is that it should be useful; the second, that it should develop responsibility; and the third, that it should have a direct application to the demands of the naval service. In specifying the particular lines of activity that naval officers should follow, the writer occupies the second part of his essay with a discussion of the training which it is necessary that naval officers should have to fit them for their work. In this connection, Lieutenant

Calkins takes up the subject of the higher education of officers. He refers to the two ways in which this education may be given: either by an institution established on a formal basis, similar to that of the Naval Academy, except that it would be for purposes of higher education, as the latter is intended for preliminary training; or by such arrangements as shall give to officers the fullest and freest opportunity to acquire knowledge and to improve themselves under the direction of a central organization with a central head, when they please, where they please, and as they please. It is evident that the preference of the writer is for this second form of naval education. Having treated that question, he takes up specifically the branches of study that should occupy the attention of officers; first, the scientific branches, then the more general group of studies, including history, political economy, and international law. In the third part of the essay the writer refers to the particular departments of the public service in which officers may find useful employment in time of peace; and therein he treats of the Lighthouse Establishment, the Coast Survey, the Revenue Marine, the Life Saving Service, the Fish Commission, and, at some length, of the Mercantile Marine,—a subject on which he is specially qualified to speak,—the Steamboat Inspection Service, and Preservation of Harbors. The fourth part of the essay is devoted to an investigation of the lines of strictly professional work that a naval officer may take up with advantage to himself and to the public service generally; and here the writer dwells upon a very important subject, as it seems to me, one of the most important in the essay, that of increasing and improving the training of officers specifically for war. He points out the singular fact that but little is done at the present time in the way of training officers directly for war as war is understood to-day; and he calls attention to the importance of enlarging the professional course at the Naval Academy, by adding to it a thorough analysis of the work done in the last war. He also takes up and treats at some length, and with considerable detail, the subject of improving the condition of the men, their education, the furnishing of libraries for the crews of ships, and the work that officers may do in this particular connection. In the same part of the essay, allusion is made to the labors of the Naval Observatory, of the Hydrographic Office, of the Office of Naval Intelligence, and to the work accomplished by the officers detailed as instructors at the Academy, whose occupation secures for them a most valuable post-graduate course.

In conclusion, the essayist takes up the subject of rewards for meritorious effort, and in this connection he condemns the English system of giving rewards by increased pay, and also the system of rewards by promotion outside of the regular turn. The conclusion that the writer reaches seems to me a somewhat discouraging one. It is practically that virtue is its own reward, and that officers must look for compensation for the efforts which they make in the special directions described by the essay, in the consciousness of well-doing that good work always brings with it.

The essay makes a strong appeal to the patriotism of officers, and presents an earnest argument in favor of their taking up some of these useful branches of investigation and of labor.

The essay is now open for discussion.

ASSISTANT NAVAL CONSTRUCTOR F. T. BOWLES.—It seems to me very important that naval officers should realize the actual force of this essay, which unintentionally represents the utter ineffectiveness of our naval force.

I say this because the very existence of this essay indicates the presence of an unhealthy state of affairs; for, scanning the Navy as it stands at present, comparing the high education already received by our officers with the degraded, inefficient condition of the men, the examples of modern naval construction with our antiquated *matériel*, it is evident that something is lacking when the remedies here suggested would all be the natural outgrowth of an energetic and well-supported naval service.

It must be astonishing to one unacquainted with the Navy to find so many remedies proposed.

Now, every one will acknowledge the proposition that a navy is an important adjunct of a government which wishes to extend abroad its influence in art and civilization. Taking this for granted in connection with the fact that the Navy receives little support from the country, we must acknowledge that we have no foreign policy—that is, apart from considerations of the diseases of cattle and the protection of Irish citizens abroad.

Until we assume some definite attitude towards foreign powers, and until we enforce respect and attention to our influence, the Navy can have no real importance.

I think that the whole spirit of the people of this country is a militant one and entirely in favor of the Navy. A gentleman whose business it was to read many small newspapers published in various parts of the United States, which really represent the feelings of the democracy, told me that during Mr. Blaine's term of office as Secretary of State, the spirit of the country was in favor of his policy, which would have been the making of the Navy. That is a remarkable fact, considering that our government, as it stands at the present, has no such support; and I mean to say that the real spirit of the people in regard to our foreign relations, and therefore in regard to the Navy, is entirely misrepresented, or unrepresented in the government, where considerations in regard to the Navy are deemed of least importance. Then, coming to the fact that we have obtained only limited support from the country—fifteen million dollars per annum—the question is asked, What have we done with it? and the answer is, nothing. That, of course, reflects upon the Navy, particularly on the Navy Department.

LIEUTENANT R. WAINWRIGHT.—While I most heartily agree that the essayist has shown the advantages, in fact the necessities, of higher education, there are some details of his scheme with which I can find fault. In attempting to draw up any scheme of education, especially of post-graduate education, or of higher education, it is necessary to look to the education of the mass.

Genius can look out for itself. In spite of obstacles, genius will certainly rise triumphant, and I believe that there is no force which will enable those who are incapable to become efficient. Therefore, I think the fault of this scheme is that it is a project mainly for those who are already students, men

already capable of guiding their own studies. While it does give to officers advantages that they may not have now, it does not point out the method of raising the standard of intelligence. In such a scheme I think a course of lectures should be inaugurated at the Naval Academy. I think anything that may be done to foster our Alma Mater should be done. By a course of lectures at Annapolis there would be additional employment for its large staff of instructors, and there would some good come out of it which would show for the large expenditures now made. At the present time there is a small showing for the expenditure, on account of the limited number of graduates allowed to go out from the Academy. I believe such a course of lectures with the aid of a number of specialists may be made useful and valuable. While officers might be required to attend these special lectures, very little of their time need be so employed. I think those already students would find no difficulty, with the aid of the library and other facilities provided at Annapolis, in using their time with advantage to themselves; and those not studious must at least be benefited. After such a course I would give all the latitude that is mentioned in the essay; but I think even then that the claims of the Torpedo Station and the Naval Observatory should not be overlooked with this object of higher education in view. I believe that certain branches of instruction can be carried higher there than in any special course at a university.

In regard to the proposed annual essay, I must wholly differ with the gentleman. I think it is very impracticable. It seems to me that in no body of men can the greater number write well, and in the majority of cases naval officers would write badly; anything required to be written by force and precedent will necessarily be carelessly done,—will tend to lower the standard of education, and tend also towards deterioration. I can hardly conceive of a sadder fate than that of those unfortunate officers who would be required by the mandate of a cruel department to read over a mass of annual essays such as this paper contemplates.

Lieutenant F. Winslow.—I regret that I was not present when the Prize Essay was read, as I should have liked to have heard the discussion that ensued; and I am equally anxious to hear all that can be said upon the subject to-night. But before further discussion by other members, I should like to call the attention of the Institute to some of the essential features of the essay and to the bearing they have upon the future.

We have now had four Naval Prize Essays. They have been written on subjects widely separated, but they have all possessed several common features. They have all been radical in the remedies proposed, and have all covered extensive ground. Particularly is this true of the first and last. These have proposed schemes neither practical nor practicable.

To my mind this essay is a most extraordinary production. A scheme for the improvement of the naval officer which not only considers his moral, financial, and literary status, but which also includes the hygienic and hydrographic conditions of our rivers and harbors, is a matter for some amazement. But the proposed general upheaval of the established customs of the service and

country is still more remarkable. The essay extends from the belly of the sailorman to the Constitution of the United States. I can think of nothing I have ever read that has the same scope, unless it is Punch's "History of Motion," which was to begin with the "first revolution of the earth, and take everything in its turn." Now, it is manifestly impossible for any one to criticize an essay of this description in one evening. I can pick out a few good or bad things, here and there, in the course of half an hour, but the discussion under those circumstances will have no serious weight in forming other men's opinions. I will not, therefore, attempt elaborate criticism, but, after running over a few particular points, I will call the attention of the Institute to certain principles upon which the essayist bases his conclusions, which are, to my mind, radically wrong.

The essay renews certain recommendations contained in the last report of the Secretary of the Navy; that is, the transfer to the Navy Department of the Bureaus of Revenue Marine, Life Saving Service, and Supervising Inspector.

I do not know that any one claims that these bureaus are not working to the satisfaction of the country. There may be faults in their administration, but they are not so great that they have raised a hue and cry; and whatever faults do exist, I think there is a very prevalent opinion among the people that there are faults infinitely greater in the administration of the Navy Department. We occupy a very peculiar position in asking for the transfer of these bureaus. We are like men in a boat that is leaky, has holes in the bottom, is getting full of water, with the crew at loggerheads and catching crabs; with no one at the helm, or, if there is, no one who knows how to steer. We see boats ahead, well manned, and safely proceeding on their way; and, recognizing our condition, we cry frantically to them to turn and take us in, and not only that, but we insist that we be allowed to take charge of the boats and to manage them. We insist upon grasping the tiller and the oars. Naturally the other crews refuse. Self-preservation would prevent their permitting it. They say, with reason, that we have made such a bad mess of our own affairs that there is danger in entrusting us with theirs. To my mind their argument is a very cogent one. The case stands thus: The Navy has steadily deteriorated of late; we have either had an influence in the affairs of the Navy and the administration of the Navy Department during the last fifteen years, or we have not. I do not say we have, for I think the reverse has been the case; but, however it may be, the inferred conclusions are dead against us and the transfer. If we have had no influence in the administration of our own affairs, what likelihood is there that we shall have any over the administration of the transferred bureaus? If we have had an influence, then we are responsible for the present condition of affairs. The conclusion seems too obvious to need statement, but it will be most forcibly stated if, however, we demand Congressional action; and the result can be readily imagined. But the principal reason given by the essayist for this transfer is, that it would be in the interest of the general education and improvement of the naval officer, and would fit him for some future usefulness. Now it can hardly be expected that Congress will turn over these different bureaus to naval officers for such a reason and as a mere experiment. It may be a good thing that naval officers

should be improved, but the country would naturally wish it to be done in some way less likely to be expensive.

Again, in regard to the employment of a larger number of officers under the Lighthouse Board and Coast Survey. There is no doubt that it would be advantageous if more officers were employed under both, but the primary reason assigned by the essayist for the increase seems hardly a sufficient one. He does not claim that such assignments would promote the efficiency of either service to any great extent, but that the duty would be a means by which the naval officer himself would be advanced, and his usefulness in the *future* be extended. But the Lighthouse Board would, as I should were I in charge of that service, object to the subordination of their special views to the education of naval officers. They do not care whether a naval officer is educated or not. What they wish is, capable officers to manage their tenders and to supervise the operations of the establishment. They have no desire to entrust the superintendence of repairs or the command of steamers to inexperienced naval officers merely to train them or to give them an education. They would naturally object; and therefore in order to accomplish the scheme, compulsory legislation would be necessary; and that, I fancy, would be difficult to bring about.

Again, the essayist says that the Coast Survey, in return for the services of officers and men of the Navy, should see that the officers are instructed in all the various branches of surveying and geodetic work. The objection just stated applies here also. The Coast Survey people will say that there is no particular reason why they should be turned into a board of instructors; that they have nothing to do with the education of naval officers; that they come to them prepared, they suppose, to do a certain kind of work, and if they cannot do it the Coast Survey does not wish them. Certainly it does not wish to instruct them.

I might take up a few more points, but I have not time. Reduce this essay to its essential feature and you will find that it is only a great scheme for promoting the education and mental activity of the Navy. Now, nobody objects either to the education of officers or to the acceleration of their mental processes, nor will any one deny that both are desirable. One cannot object to the statement of a general principle. If a man says that sick people need medicine, one cannot find fault with the statement. It is only when he states the specific remedy that should be applied to the disease that one can take exception. Therefore, while I must agree with the essayist in thinking that disease exists, I decidedly disagree with him as to the remedy he proposes. Look through the essay and you will find that this proposed remedy is an extensive system of study and investigation of everything of interest and importance to the civilized world, with, perhaps, a slight leaning in favor of the interests of the naval service. Now this system appears to me not only wrong, but impracticable. The essayist proposes a Director of Studies who is to decide what study each officer of the service is to take up, basing his decision upon the character and fitness of the individual for any special branch. This would require an intimate acquaintance with every officer in the service. I do not know how many officers there are—some two or three

thousand, I think—but it is certainly as much as any one man could do to become acquainted with them all. But that is not all this Director would have to do, by any means. After achieving intimacy he must direct their studies into such channels as their personal qualifications would seem to render advisable. A "thoroughgoing specialist," however, is to be allowed full liberty in the selection of his study.

Now, it is hardly possible that any one urging this can have carefully considered what this Director of Naval Studies is to be. He is to be a master of all arts and sciences—for there is no limit to the subjects the naval officer may take up. For instance, the Director must have a knowledge of navigation, gunnery, seamanship, steam engineering, and all the collateral branches of the naval profession. That would seem enough, but the plan of the essay contemplates much more. It is especially advised that study and investigation of matters in no way connected with the service should be pursued. The Director, then, must understand the arts and polite literature, law and political economy, and all the sciences; for he is to be prepared to follow the "thoroughgoing specialist," whatever such individual may be, wherever that "thoroughgoing specialist" may take him. Now, the arts and sciences are pretty wide, and very few men in this day undertake to master more than one of them, or even part of one. But the Director must be master of all. In science he must be not only an anthropologist, but an ethnologist, an ethnographist, a heliologist, an archæologist, and a philologist; not only a zoölogist, but also a histologist, embryologist, homologist, morphologist, anatomist, and palæontologist. He must be a chemist, botanist, and electrician; must be familiar with branches without end—subjects innumerable. He must be prepared for all things; for the thoroughgoing specialist may drag him from the solar system after its disarrangement by the repulsive force of the sun, to the minutest details of quantitative analysis. Suppose he is carried, as he may be, into zoölogy; from the general science into one of the branches, say the invertebrates; from the invertebrates into one of the four great groups; thence into the orders numbering tens and twenties in each group; thence into the classes numbered by hundreds in each order; from classes to genera; from genera to species or varieties numbering hundreds and thousands to each genus. This Director must know them all; must be prepared to elucidate any question; and, Mr. Chairman, it is possible that he may be torn from the contemplation of the legs of an Apollo or the arm of the Venus of Milo to the study of the alimentary functions of the *Gregarinidæ*, which are parasites of the intestines of the common tape-worm.

Now, it is possible that, through the operation of the laws of evolution and survival of the fittest, we may get, in the course of time, an omniscient Director. But it seems hardly possible that in the present day, or in the lifetime of any here present, such an intellectual giant will be produced. But aside from the evident impossibility of carrying out the plan so far as the Director of Studies is concerned, is the remainder possible? and, if possible, would it be of advantage to the service? As a matter of fact an officer can, at the present time, study anything he pleases; he may write as many essays or make as many collections as seem to him desirable. But how many do so? And, if few are

so employed now, has the essayist proposed any method for increasing that number? I find that there is little or no important change contemplated in the present detail of officers, except that more are to be employed in the Coast Survey and other establishments. And as the same force is to be kept at sea as at present, whence is to come the corps that is to be devoted to study? Is it supposed that many officers will voluntarily take up additional work without additional reward? Such has not been our experience in the past, and there seems no ground for believing it will be changed in the future. The new order of things is partly compulsory, partly optional. No reward is offered for a good essay; no punishment for a bad one. The officer is to be allowed, or ordered, to do something, or anything. We see how large an amount is accomplished when the work is optional; and though the quantity may increase when it is compulsory, have we any right to expect more than perfunctory work under such circumstances? and of what value would that be? No man has reached eminence in any profession in the world by occasional application only. You will find that the great leaders in science, art, or literature have become so only when they were well on in life, and when their whole previous existence had been one of constant, unremitting labor. It is hardly to be expected, then, that an officer devoting every alternate three years to some profession or science, in addition to more or less naval duty, should accomplish much or become very prominent. He will always be a subordinate, always be considered an amateur, and his labors will tend, not so much to the increase of his own reputation as to that of his master, and not at all to the advancement of the reputation of the Navy. We must realize that our fame and that of the service can be enhanced only by the successful performance of *naval* operations, by work that requires the exercise of our *naval* faculties. By engaging in outside pursuits we may achieve some personal distinction; but it is the man that is distinguished, and not the officer nor the service.

In this hasty review of the specific remedies proposed in the essay, it may be said that, condemning much, I suggest nothing. At this time and place it is not necessary for me to suggest anything. We are met here to criticize and discuss this essay, and, considering its extent and variety, we have not time even for that. Certainly we cannot elaborate a better plan in a half-hour, and I will not attempt to do so; but before I close I would like to call attention to the effect such a course as that indicated by the essay will be likely to have upon the future of the service. Reduce this essay to its essential features and you will find the burden and refrain of the song is—study, write essays, send in reports. The individual officer is to be directed into scientific work, into artistic work, into literature, into almost anything except the study of the naval profession; but especially is he to devote himself to scientific work. Now, are those studies, which are mainly of a scholastic nature, of the kind the Institute believes will conduce to the future efficiency of the officer? Remember that the training of scientific men is wholly different in plan from that of active and practical men. The whole history of modern science shows that a man never arrives at conclusions except, I may say, logically. It is the deductive

method he pursues. In the course of time such a training will naturally make that man study well, not only everything he sees, but everything he does. His authorities must be behind him. Every act, every word, is to be based upon sound postulates before done or said; such is the tendency of his training. But it is necessary that the mind of the military man, and especially of the naval officer, should be trained by a method exactly the opposite. His actions must be apparently intuitive. He must know and do by instinct rather than by mental action. The emergencies that arise with him cannot be easily foreseen. He cannot state even to himself the *pros* and *cons;* such hesitation would make disaster imminent, if not certain.

War, whether on land or on sea, is not an exact science. It cannot be reduced to purely scientific methods. Much, sometimes all, depends upon the courage or audacity of one side or the other, and these factors cannot be eliminated from the problem. If they are, the eliminator will find all his calculations are upset. Yet to just such a course will the scientific and scholastic training lead. Courage, daring, endurance of ships, guns, and men, influence of wind and sea, are factors that, having a variable value, are apt to be discarded by the scientific mind. Accustomed to deal with hard facts, indisposed to admit hypotheses, never taking chances, and coming to a decided opinion only when each successive step has logically and clearly led to it,—the mind so educated is totally unfitted to control operations whose success depends largely upon qualities the importance and value whereof have not been considered. If you will read the history of naval wars and of naval operations you will find that the successful men are those who dared, and not those who reasoned. Their actions were not based on what would be called sound postulates; they were guided by instinct, by intuitive perception. Their conduct was the result of dependence upon factors, influences, whose value was unknown. What they realized was that the laws of war are not immutable, and that the great commander makes, rather than follows, them.

Farragut passed the forts in spite of the advice of all the captains of his fleet, because he *dared* to do it. Nelson attacked the French fleet at the battle of the Nile when the chances seemed all against him; and I fancy if any one looks over the course, he will find success in naval warfare is not so dependent on reasoning as it is on courage, pluck, daring, and ability to take the chances. Now, these seem to me the qualities one should strive to inculcate in the officer, and I doubt very much if it is possible to inculcate them except in the active practice of the profession. I am sure the profession cannot be actively practiced in a studio, or laboratory, or in the pages of a magazine. I agree with the essayist that responsibility is the best experience a man can have, but very much depends upon what the responsibility is and how it is exercised. The man that decides upon the character of a fish or of a work of art does not assume the kind of responsibility that will rest, sooner or later, on the shoulders of the naval officer. The former has plenty of time in which to make his decision, can consult any and all authorities, and no great disaster can follow a mistake. If he is not sure he does not speak, and his risk is reduced to a minimum. The responsibility of the naval officer, however, is wholly

different; it is the responsibility of taking chances—of following one course or another, and it sometimes does not matter which, so long as it is taken promptly—when everything appears against both. Are those trained in the closet likely to assume responsibility of that kind?

Now, one other thing. We people of the Navy are becoming dissatisfied with a position that is a necessity in time of peace. We are beginning to recognize that we are not essential to the Government or country except occasionally. We must also realize that we necessarily occupy subordinate positions except occasionally; and, too, we must remember, when we attempt to change the order of things and the service so as to increase our importance and usefulness in time of peace, that we run very great danger of impairing our efficiency in time of war. We must remember that these days are not our days; not days for the exercise of our peculiar calling. We must be content to bide our time. When that time comes, the man who is the best officer will have been most useful. If his preparation *in his profession* has been thorough, he is the man that will succeed, and to the achievement of such success should our efforts and training be directed. That any one should think otherwise, that any one should hold up to the naval officer as most worthy of his efforts pursuits other than his legitimate one, is to me astonishing. In no other profession can you find such a course advised. If you ask the butcher, the baker, or the candlestickmaker how he can be most useful, he will undoubtedly tell you, by attending to his own business. But if you ask a naval officer the same question, he tells you, by being anything in the wide world except a naval officer. This is a sad commentary on our condition. It is a tacit admission that the Navy is useless in the present, and likely to continue so in the future.

And it is to that future that I would call your attention. When the day comes and we are commanding vessels or fleets, if we experience disastrous failure, if we are whipped and are annihilated, it will be useless to plead in excuse that we have described a new species of bug, that we have discovered a new statue, that we have written essays on polite literature which have been favorably noticed. The people will naturally feel that they paid us to be naval officers, to prepare ourselves for fighting, and to fight successfully, and they will naturally expect us to do what we were paid to do.

I, for one, am unwilling to see such a course adopted in the service as will make the Navy of the future liable to reproach. I do not care for any future historian to paraphrase Macaulay's famous sentence regarding the navy of Charles II. and James II.; I do not wish my descendants nor those of other naval officers to see in the pages of history a phrase like this: Doubtless there were in the Navy of the United States both seamen and officers; but the seamen were not officers, and the officers were not seamen.

LIEUTENANT W. H. H. SOUTHERLAND.—While I do not agree with all that is contained in the essay, I must say that I almost wholly disagree with the gentleman who has just finished speaking. In his discussion he has certainly gone to an extreme. In a long speech, he has found fault with everything

contained in the essay, but has failed to make any suggestion in regard to the subject-matter. He considers the essay to be "impracticable and unpractical." I must admit that it may seem so on first glancing over it, but a careful consideration of some of the various means proposed will cause us to admit their practicability in some degree.

In the discussion of this essay I trust that feasible means of carrying out some of the suggestions contained in it will be proposed, and that they will meet with the approval and consideration of the Department.

It is useless to say that any one person can be found to perform the duties of the proposed Director of Studies, but I see no reason why we cannot have in each branch of our profession, and under certain circumstances, an officer who can perform the duties of Director of Studies for that branch. At the Naval Academy each head of a department is a Director of Studies for his own department. At the Torpedo School the Superintendent assumes the duties of a Director of Studies pertaining to torpedo warfare.

Now, as to the opportunities for improvement by study. A post-graduate course at the Naval Academy is certainly practicable. At the present time each officer who is there on duty is, in reality, taking a post-graduate course. Naval cadets, after their two years' service afloat, should be permitted to take a post-graduate course at the Academy for two academic terms—one academic year. Officers of higher rank, who do not care to become instructors, but who desire to take an advanced course in any branch taught at the Naval Academy, should be ordered there for one or two years. Every facility for improvement should be afforded them. Should any fail to take advantage of their opportunities, the Superintendent would find the Department ready to order them away. The length of the term for instruction at the Torpedo School could be increased to one year, and the same plan carried out there that I have suggested for the Naval Academy. A few of those cadets who have no desire to take a post-graduate course at the Naval Academy or at the Smithsonian Institute, could be ordered to the Naval Observatory for a few months in order to learn the practical use of the various instruments at that place. Of course, all this should come during an officer's term of shore duty, and nothing should excuse him from going to sea in his regular turn.

I think that many officers seek to improve themselves while at sea, and I wish to call your attention to the fact that much can be done in the way of improvement on board ship. Each sea-going vessel in our service has at least one graduate of the Torpedo School on board. It only requires an order from the Department to have this officer instruct the other line officers of the ward-room and steerage in the practical use of torpedoes. This can be done while at sea, and it would result in giving each line officer in the Navy some practical idea of torpedoes, and would be an excellent preparation for the advanced course of instruction at the Torpedo School.

I do not take it for granted that Lieutenant Calkins really means to go to an extreme in the matter of study. I think he simply desires to open every possible means for an officer's improvement. For my own part, I think this improvement can be obtained on board ship and at shore stations, in the line

of the legitimate duties of a naval officer. I think the Department should put it in the way of officers on shipboard to learn all that may be of practical use during a cruise. Lieutenant Calkins mentions photography as one of his useful studies. Let the Department put a photographic outfit on each vessel of the Navy, and commanding officers will always be able to find young line officers ready and willing to learn its use. They can easily make the emulsion and prepare their own dry plates, and, with a little practice, can take views of prominent headlands and coasts on a survey, or of anything that may be of professional interest. They may not succeed in making excellent photographs at first, but they will improve with practice.

The Department now has it in its power to give young officers some little chance to handle vessels. Any young lieutenant would be only too happy to have the command of one of our Navy Yard tugs. Such command could be of a year's duration, in which time any young officer of intelligence and zeal would gain much practical experience.

The gentleman who preceded me spoke of Farragut and Nelson as instances of great naval commanders who acted by instinct alone. Every student of naval history will say the contrary. Reason, not instinct, convinced Farragut that some of his vessels were sure to pass the forts; that the forts could not keep up a fire that would sink all his fleet. It was not instinct that led Nelson into the battle of the Nile. He knew what English sailors and English ships had done in the past, and he reasoned that they could be trusted to do the same again.

Lieut. Winslow is averse to the transfer of the Coast Survey to the Navy Department. I think that the law which now prevents the Navy Department from doing the hydrographic work of our own coasts should be repealed. I am sure that the essay makes it very plain that officers of the Navy should know our own coasts, and only in the Coast Survey can they obtain a full knowledge of it.

LIEUTENANT J. R. SELFRIDGE.—I came here this evening with no intention of taking part in the discussion, but there is one point that has not been touched, upon which I desire to say a few words.

I think the impression received after reading the essay is, that in time of peace we should devote ourselves to such studies as will produce the best possible effect on the public mind, even taking up subjects that have no bearing upon our naval education, and which do not tend to perfect our knowledge of professional duties. The highest aim of a naval officer should be to govern his men, to handle his ship in a seamanlike manner, and to possess a thorough knowledge of modern warfare.

We require as good seamen now as in the old days—yes, even more so; and the officer who desires to stand at the head of his profession must make his mark as a good seaman.

I regard the higher order of specialties as accomplishments, which are of minor importance compared with the grander duties that lie directly in our path. I think, therefore, it would have been better if the essayist had dwelt

longer on this point, and had given greater prominence to our professional duties, which, as the Chairman has just stated, are fourth in order of divisions into which the essay is divided.

The subject of fleet manœuvres is dismissed in almost a line. I think this is a very important subject, and one that can be studied with greater profit to ourselves, than can a new professional specialty,—natural history, for instance.

The naval officer of the present age can keep pace with the improvements of the day only by constant application, and I believe his time will be fully occupied in pursuit of legitimate work, so to speak, without stepping aside to seek for knowledge that can be of no practical value to him as a naval officer, or to the country at large.

ENSIGN W. I. CHAMBERS.—I am very much interested and instructed in listening to the discussion of Lieutenant Calkins' valuable essay this evening, and wish to add a few remarks on a point that seems to me to have been somewhat slighted. The time already consumed in the discussion makes me hesitate to prolong the meeting, and induces me to maintain silence; but as this discussion will be read by many in its printed form, I should like to add a few words, if possible, even at this late hour.

In the essay, the special study of international and municipal law, political economy, and social science, is recommended, and I wish to say that I think the pursuit of these studies would not only tend to develop qualities very requisite in every officer, without detriment to his other professional attainments, but would also prove of the greatest value to the naval service and to the country. By familiarizing officers with the needs of the nation, we should enable them to take an active part in establishing and maintaining with credit a settled policy, of which the country stands so much in need. And it seems evident to me that in the pursuit of these studies the mass of naval officers themselves would become convinced that the maintenance of a navy commensurate with the best interests and dignity of the nation is an actual *necessity*. When officers become so convinced and are able to explain intelligently their ideas to the great mass of citizens and legislators with whom they are constantly brought in contact, we may hope to have at least a *matériel* in the maintenance of which officers will find ample opportunity to obtain much coveted practical experience in the handling of modern ships, and to keep pace with the constantly progressing requirements of a modern naval officer.

I am a firm believer in these three principles: (1) naval superiority or excellence and commercial prosperity go hand in hand; (2) commercial prosperity is vital to the best development of our country and to the happiness of its people; (3) both naval excellence and commercial superiority are necessary factors with us, if we are to maintain our peace with all nations or prevent future embarrassment and financial ruin, which are inevitable results of a long-continued weak and decaying condition.

Now, I believe also that it is within the power and province of the naval officer to bring about among the people an understanding of these facts; and when the thinking portion of the nation becomes satisfied of the advantages to be de-

rived from the maintenance of a navy, it will become an easy matter to construct one.

It may seem absurd to some that I should imply that the views of all naval officers are not well settled as to the importance of a navy in time of peace, but I have come to believe that they are not, from conversations with many officers on the subject.

In one instance I was told by an officer, whose opinion and ability to express himself made his ideas usually highly respected by his shipmates, that after due deliberation he had come to the conclusion that the United States needed no navy, and that wars with us were a thing of the past. I promptly replied that if I could bring myself to think as he did I should consider I was leading a worthless life and feel disgraced by holding a commission in the naval service.

I have also been told by intelligent men of good social and political standing, men living not in the far West, but very near that proud commercial centre, New York City, that they considered the Navy a useless burden on the public funds, and that naval officers were created only to draw their salaries.

Such views as these often arise from pardonable ignorance, which the naval officer, if properly informed, may be able to correct, and which he should correct.

Briefly, if we expect to fit ourselves for the requirements of modern warfare, in time of peace, we can do it with advantage to the service and country by increasing our knowledge of "*affairs*," and by consequently extending our influence with the people, to the end that a creditable naval establishment may be created and intelligently maintained.

LIEUTENANT C. G. CALKINS.—Of course it is not my intention to attempt to reconcile all members to my views. When gentlemen begin by finding that the essay is absurd and monstrous in its scope, and that its fundamental principles are wholly wrong, the differences between us are irreconcilable. We have not time to take up fundamental principles. It seems hardly worth while to attempt to modify such views at present. But I must say that a criticism long enough to occupy a very considerable portion of the time taken to read the essay, and which is merely negative and destructive, is not very well calculated to elucidate the subject.

The remarks made by the first gentleman who spoke after the Chairman were somewhat general in their character. The next gentleman made a very definite point, upon which his opinion seemed to differ with what I meant to express. I do not think that it is possible to give a higher education to every naval officer. It is therefore not necessary or proper to apply any of these schemes invariably or uniformly to the whole mass. They must be made exceptional for exceptional cases. They must be made to afford opportunities to people who would use them.

Now, a great deal has been said about the supposed neglect of naval specialties. I do not think that measuring by the foot-rule, or by any other standard, the space given to these subjects, they will be found to have been slighted. What I recommended is that officers be allowed to take up things now neglected; purely naval duties were considered and special attention was called to military duties that I consider to be now almost

wholly neglected. Some people think we do not need any preparation for war.

In spite of the personal courage of the French generals in the war with Germany, those who did not care much about knowledge and military studies, when they came in conflict with the Prussian army, organized upon a scientific basis, were utterly paralyzed in regard to the handling of their troops. They found they had no courage, for they felt that they were ignorant. Von Moltke, who may be supposed to be a practical man, says that the man who feels his ignorance "floats irresolute, and is ready to yield to demoralization." It is impossible for the will to be strong and for resolutions to be formed quickly if the man feels that he is ignorant. If he knows he is ignorant, he is weak; and if he does not know it, the matter is still worse.

Two or three examples of instinctive audacity as opposed to reasoning have been cited. Farragut's attack on the Mobile forts was one of them. He had few opportunities when he was young, but he showed a taste for the cultivation of foreign languages, and was better prepared to use them than almost any officer of his standing in the service. When in Mexico, at the time the French bombarded Vera Cruz, he endeavored to find out what practical lessons could be drawn from their experience, and he endeavored to induce the authorities to make use of his studies and conclusions when we went to war with Mexico. When the Crimean war broke out, he made application to be ordered abroad to study actual naval warfare. That is the kind of post-graduate course he desired; and that is what I recommend for officers at the present day. He wished to go to the Crimea because he thought no officer in the service had studied naval warfare more energetically, or was better prepared by knowledge of foreign languages to acquire information of value to the country and to the service.

The name of Nelson has been brought up. In the first part of the essay I quoted a remark in regard to Nelson by a man who knew him well and admired him very much, from which it appears that from the earliest moment he devoted himself to the study of methods for handling a fleet, to the neglect of the details of the profession then deemed of prime importance. He constantly planned fleet manœuvres. Of course he was a man who knew how to handle his own ship, but, far from devoting himself exclusively to seamanship, he had neglected it.

Some of the detail criticisms require a little attention. In regard to the transfers of various services proposed, of course legislation is required, and I do not think it is easy to get. It is not required for changes in the Lighthouse Service, and the changes suggested are intended particularly for the benefit of that service. It seems to me that when a man goes there now he is a little too old to learn the duties of an inspector, and it would be a great deal better if he had a few years service as assistant-inspector. The Lighthouse Service would be well paid for training their inspectors before they give them authority over such an immense stretch of coast as we have in some districts, where it is difficult for any man to familiarize himself with an inspector's duties.

In the Coast Survey, naval officers are often detailed for duty a second time; and it would be well if the authorities in charge should give these officers a

more varied and more thorough training in the first instance before they are called upon to take charge of a party, with important duties to perform.

In regard to the Revenue Marine and Life Saving Service I have said little in the essay, and have nothing more to say at present; but as to the Steamboat Inspection Service, if there is any satisfaction in regard to its operations, it is due to ignorance as to the way it is managed.

The Mercantile Marine has declined and decayed until few know or care to inquire how it is mismanaged and how its revival is obstructed. When masters and mates of steamers are to be examined, it is absolutely necessary that the examiners should be seamen. At present, no matter where a ship goes, her officers are all examined by men supposed to be shipbuilders or engineers. In England, naval officers are employed as examiners, although the Admiralty is not always able to spare them, for there are ships enough to employ them. If we had the fleet of England we should not be talking to-night about extending the usefulness of naval officers.

I have referred to a number of studies in natural history, languages, law, and to a great variety of things upon which I laid very little stress. It is actually proved that there are officers seeking opportunities of improvement in these branches. I do not think it would be wise as regards the future usefulness of the Navy, that we should exclude officers from such opportunities as they now enjoy. We should, however, have a systematic way of assigning them to various studies. I laid most stress upon matters pertaining to the reconstruction of our navy and the development of our resources in time of war. The Navy must have in it men capable of designing guns, ships, and engines,—work that requires scientific knowledge; at the present day you cannot separate scientific knowledge from practical experience. When it has been done, it has usually resulted in serious complication and disaster. It is not done now by any successful business firms in the world. They go to men who have thorough scientific training in the specialties relating to the work that is to be done.

The subject assigned by the Institute for an essay was one that seemed to me to call for extended treatment; and for the very purpose of inviting criticism I made a number of specifically detailed suggestions that I had not any great time or opportunity for studying or working out, and I am very glad that they have been criticized, as they have been by some officers, with the view to make them practical. Criticism is always welcome; but criticism based upon general dislike of everything proposed does not advance the subject very far. The main point upon which naval officers can have anything to say or do that shall lead to practical and immediate results, is what I treated of in the fourth division of my essay, that is, their extended usefulness in connection with naval duties. I did not talk about seamanship drills or the handling of men, because I considered the usefulness of naval officers in that respect as at any rate recognized.

I may have failed in recommending measures that may be carried out, but it seems to me that one consideration is worthy of attention; that of preparation for military duty. I have rarely seen anything on board ship that looked to me like preparation for warfare. I have seen fleet evolutions and much drill with sails and spars; but it seems to me that if a torpedo attack were to be repelled—

if, for instance, six torpedo boats were to approach a vessel with the preparation now made to resist such an attack, there would be hardly an officer or man who would understand his duty. There is no instruction requiring such drills to to be held, and I certainly think that torpedo attacks could not be successfully repelled unless every man understood what he had to do. It would be doubtful if the ship could repel the attack even then. The men should be exercised with special regard to possible torpedo attacks. Until this is done we can hardly say we are prepared for war or that we are doing anything towards making our ships men-of-war.

The only suggestion made by the gentleman whose criticism went farthest was, that we should have some better system of promotion for the higher grades of the service. Undoubtedly, by a great deal of study—not by haphazard legislation—some improvement might be made. But it is better to begin with younger officers, who can combine their studies with their practical duties. I think that is a great necessity and an advantage.

In regard to the practicability of this essay or the schemes recommended therein, I do not know what is practicable in our service. The best authorities state that in the Prussian army a rule similar to the one proposed in regard to military studies and reports is enforced in the most absolute and rigorous manner. No officer who skims over a military question of any importance will be promoted. No general or colonel (through whom these papers are forwarded to the Department) who neglects to study them out and to make a fair scientific criticism, will be advanced or even allowed to retain a command. Such a system enables officers to learn to handle their army in view of the contingencies of war. The thoroughness and value of this system may be seen when we consider that the Prussians were enabled to finish the Austrian campaign in seven weeks, and to destroy the French army in a little longer period. The Prussian army was trained and handled by Von Moltke, who was a scientific man if ever there was one, and who had the experience of forty years of active service to supplement the knowledge acquired by study. The Prussian army is thoroughly and scientifically prepared for war, and it receives that training in time of peace or it could never be ready for war.

The necessity for scientific study of the art of war to prepare men for the duties of command was demonstrated at Sebastopol and at Plevna. At Sebastopol, brave but unreflecting officers could see nothing to do but to sink the fleet and abandon the town as soon as the allies effected a landing. But Todleben went to work with spades and picks, and prepared the town for defence, and held it long enough to save the honor of Russia and to exhaust her enemies.

At Plevna, ignorant and audacious generals sacrificed fifty or sixty thousand men in a series of headlong attacks. It became necessary to send for Todleben, and he came and drew lines around Plevna, shut the Turks up there, starved them out, and captured their whole army with small loss to his own. He successfully carried out modern and scientific methods for investing a town.

These things, it seems to me, show that science and reasoning have their applications in modern warfare. There is no trade, no industry, no business

enterprise of any kind that does not recognize the necessity of scientific men. I am far from hoping that the suggestions of this essay will be carried out in my time, but I think many of them may be elaborated, modified, or transformed until they are made of some use to the service. I really think that I did consider what I was doing while writing. I do not object to a spirit of criticism. If we had had no sharp criticism, the meeting for discussion to-night would have been a complete failure; and the Institute may be congratulated that we have had some active discussion. I am much obliged to those members who have given the paper enough attention to enable them to criticize it.

THE CHAIRMAN.—In closing the discussion this evening, I cannot help saying that I feel sorry that the most active part of it did not take a more specific direction. The main criticism of the paper, which was a very comprehensive criticism, struck at the general principles that underlie the whole subject, and it appeared to me that it seemed to find some little fault with the writer of the essay for having written an essay at all on this subject. Now, the question before the writer was, How may the sphere of usefulness of naval officers be extended in time of peace with advantage to the country and the naval service? In making a general criticism on the fundamental principles of the paper, it was at least incumbent upon the critic to suggest or to indicate some way in which this particular question could be answered, other than that which is contained in this essay.

With regard to that part of the discussion which touched upon the studies necessary for a naval officer, I may venture to suggest that although scientific study, that peculiar form of investigation which is pursued in the exact sciences generally, particularly in the higher mathematics, may not perhaps be conducive to the kind of reasoning and mental discipline that an officer most needs in moments of critical emergency, yet you must in these days develop men in the special directions for which they are specially fitted. You cannot afford to lose the services of a mathematician, if you have one in the Navy, or again of an accomplished physicist, or of a man who is eminent in any other branch of scientific research, even though his qualifications as a naval officer may not be very materially furthered thereby.

There is one point to be directly considered in all these matters; and that is, the strength that the Navy has in the community and before the country. Now, it is not to be denied, for a moment, that if you produce an accomplished astronomer, physicist, or mathematician in the Navy, the Navy has made an immense gain; that the Navy is stronger before the country. If it produces men able to speak to the scientific men of the country *ex cathedrâ*, in a way that will compel respect and attention, its influence with the country and with the scientific community is vastly increased; and this influence is a thing that it is very important for the Navy to secure.

With regard to the other studies,—the non-scientific studies,—history seems to me particularly useful, because it widens the scope of a man's observation and interest. International law, social science, and municipal law, to which Lieutenant Calkins directed attention, and, more especially, administration and the science of affairs, are matters exceedingly valuable to the naval officer; and

any experience in that direction is a great gain to the Navy. Some allusion was made to the influence that naval officers exert on naval administration. Now, I do not think that anything can promote that influence more than experience in affairs and a knowledge of affairs—a knowledge of the way of dealing with men, a knowledge of business, if you like, a knowledge of administrative work. Occupation in kindred branches of the public service might possibly give officers some experience of a character that they could not otherwise get; and as the subject-matter would be closely allied to their own profession, they would not be losing a day in professional improvement.

As to the question of writing reports, and as to the practice of requiring officers to write, there came into my mind a few moments ago a sentence that occurs in one of the letters of a very remarkable man, whom nobody will deny to have been a great naval officer, a fine seaman, and a man of splendid dash and courage—Captain John Paul Jones. In 1778, I think it was, in writing a letter to the Marine Board at Philadelphia, Paul Jones makes use of these words: "No person other than a gentleman, as well as a seaman, both in theory and practice, is qualified for a commission in the Navy. Nor is any person"—and here is the remarkable part of this statement in connection with the subject of writing reports—"Nor is any person fitted to command a ship-of-war, unless he is capable of expressing his ideas on paper in language that becomes his rank." I think that is strong testimony from a high authority to the usefulness of that kind of practice to naval officers.

I would like to put in a special plea for the study of naval history and biography. I must say I do not think there is anything more useful to a naval officer, after acquaintance with the practical details of his profession, than familiarity with naval operations as they have actually been conducted—with recent operations particularly, if students cannot be induced to go farther back. Naval biography is only naval history from another point of view. There is no better study for the naval officer than to take up the lives of his predecessors, and see the way in which they overcame the difficulties they had to meet. The same difficulties or similar difficulties are to be met with in the future, even though science has changed considerably the art of warfare. I do not see how men in any profession are going to cope successfully with their difficulties unless they study the methods of the masters in the art. Take Sir Philip Broke, for instance; or go as far back as Robert Blake; or take Nelson, or Farragut, or Cushing; or, best of all, take Lord Dundonald, who may be regarded as the typical naval officer, and study each one's career. Even the ablest men cannot fail to profit by studies of this kind.

With regard to the other branches of the government service that have been alluded to, I do not propose to say anything in particular except that the occupation of naval officers, in the direction indicated by the Secretary's report of last year, in conducting all the work of the government upon or in connection with the ocean, would be of benefit to the Navy and to the other services as well. Lieut. Calkins has pointed out in his essay very serious defects in some of these services. If the proposed transfer were made, there is every probability that those defects would be largely removed.

NAVAL INSTITUTE, WASHINGTON BRANCH.

FEBRUARY 11, 1884.

LIEUTENANT-COMMANDER W. M. FOLGER, U. S. N., in the Chair.

MACHINE-GUNS. THE GATLING GUN: ITS POSITIVE FEED, HIGH-ANGLE FIRE, AND USE IN WAR.

BY DR. R. J. GATLING.

It requires no gift of prophecy to predict that machine-guns are destined to play an important part in future wars.

They hold the same relation to other arms that the railway bears to the stage-coach, the reaper to the sickle, the sewing-machine to the needle, etc.

Of this class of arms, there is none that excels the Gatling gun in originality of design, rapidity of fire, and capabilities as a weapon of warfare.

The main features of the gun may be summed up as follows:

It has, usually, ten barrels and ten corresponding locks. In working the gun, the barrels and locks revolve together; but, irrespective of this motion, the locks have a forward and backward motion of their own. The forward motion places the cartridges in the chambers of the barrels, and closes the breech at the time of each discharge, while the backward motion extracts the empty cartridge-cases after firing.

The gun is loaded and fired only when the barrels are in motion from left to right; that is, while the handle, or crank, is worked forwards. When the gun is in action there are always five cartridges going through the process of loading, and five cartridge-cases in different stages of being extracted, and these several operations are continuous while the gun is being worked. Thus, as long as the gun is fed with cartridges, the several operations of loading, firing, and extracting are carried on automatically, uniformly, and continuously.

THE POSITIVE FEED.

The earlier model Gatling guns had cartridges fed to them by means of feed-cases, or by a drum, but recently a new method for supplying the cartridges to the gun has been devised, which is *positive and certain in its action.* In the old methods of supplying ammunition to the gun, there was a liability that the cartridges would become jammed in feeding down from the feed-cases into the carrier or receiver; but in this newly-improved feed, the mechanism never loses control of the cartridges from the time they leave the feed magazine until they enter the chambers, are loaded, fired, and the empty cases extracted. With this new feed it is impossible for the gun to fail in its operation, even when it is worked by men unacquainted with its use. This new improvement not only greatly increases the rapidity and certainty of fire, but also enables the gun to be fired at the rate of over 1200 shots per minute, and at all degrees of elevation or depression, which is something no other machine-gun can do. By firing the gun at proper elevations, ascertained by means of a quadrant, the bullets discharged from it can be made to fall upon men behind breastworks or entrenchments, at all distances, from 200 to 3500 yards from the gun. This "high-angle," or "mortar" fire adds greatly to the effectiveness of the gun, and will, no doubt, prove of inestimable value in future warfare.

Experiments have proved that musket-size balls, fired from a Gatling gun at high angles, strike the ground with a force sufficient to penetrate from two to three inches of timber. About 1200 shots per minute can be fired from the gun, raining down a hailstorm of bullets on the heads of men behind entrenchments, thus making such positions, in a short space of time, untenable. Open breastworks, or uncovered entrenchments, would furnish little or no protection to troops against the fire of this formidable weapon. Trials were made with a Gatling gun, having this improved feed, at Sandy Hook, N. J., during the months of July, August, and September, 1882, and in January, 1883, by the United Sates Ordnance Board, composed of the following officers: T. G. Baylor, Lieutenant-Colonel of Ordnance, President of the Board; George W. McKee, Major of Ordnance, and Charles Shaler, Captain of Ordnance.

The following extracts are taken from their report of the trials:

"The object of the experiments was two-fold: first, to test the new feed magazine; second, to ascertain the effect on targets placed horizontally on the ground, at distances of from 200 to 3000 yards, as regards penetration and accuracy."

In speaking of this new feed, the Board say in their report:

"The action is, as claimed in the inventor's description, positive and continuous as long as the gun is worked. The substitution of a positive action for one depending upon the carriage of the projectiles to the grooves of the carrier-block by means of gravitation, modified by friction, is a great improvement. The gun works as well when the feed 'magazine' is horizontal as it does in an inclined or a vertical position. No jamming, or interference of any kind, occurred during the trials, and the rate of discharge varied uniformly with the revolution of the crank necessarily."

In speaking of penetration, the report says:

"The penetration from 3000 to 1000 yards was through two inches of spruce plank, and from three to five inches into the sand, the projectiles striking point foremost."

The gun used in the trials was 45-inch calibre, with barrels 24 inches in length; and the ammunition used contained a charge of 85 grains of powder, and a bullet weighing 480 grains.

In firing at high elevations, to have the bullets strike the ground at various distances, the following elevations were given the gun: At 200 yards range, the gun was fired at an elevation of 88½ degrees, the bullets so fired remaining up in the air 57 seconds from the time they were discharged, until they struck the ground.

At 500 yards range, the gun was given an elevation of 85°.

At 1000 yards range, the gun was given an elevation of 77°.

At 2000 yards range, the gun was given an elevation of 66°.

At 2500 yards range, the gun was given an elevation of 56°.

At 3000 yards range, the gun was given an elevation of 24° 40′.

At all ranges, when the gun was fired at and below 85° of elevation, the bullets struck point foremost, and retained their rotary motion, as was proven by spiral scratches on them, caused by friction in their passing through the boards.

Extracts from the official report of the United States Army Ordnance Board, on the trial of the model, United States calibre (0.45-in.), Gatling gun, at Sandy Hook, N. J., in January, 1883:

The gun is similar in general to the one described in the last report of the Ordnance Board on the subject.

The *lock* is called a rebounding one, the intention being that the firing-pin shall not project in front of the face of the lock until, when released from the cocking-ring, it flies forward and discharges the cartridge.

A device allows the cocking-ring to be thrown out of action at will, and prevents the cocking of the hammers. This is of advantage during drill, and allows firing motion to take place without snapping, and thereby injuring the hammers.

RAPIDITY OF FIRE.

Date.	Kind of Cartridge.	No. of Rounds.	Time.
January 6, 1883.	405 grain bullet.	812	45¼ seconds.
January 6, 1883.	500 grain bullet.	816	45¼ seconds.

The object of the experiments was to test further the new feed-magazine in its adaptability to the use of the service cartridge, both with the 500 and 405 grain bullets, and also to test some new features of the gun and carriage above described. The Board, in its report of October 11, 1882, on this "feed-magazine," when applied to a gun using the English bottle-shaped cartridge, states that it "is all that is claimed for it, and adds very considerably to the value of the gun." In that experiment the gun was fired at various degrees of elevation from 1° to 89°, but in these experiments the gun was fired several times, as rapidly as possible, with 8 and 9 feed-magazines previously filled, and with both kinds of cartridges. The gun was finally dismounted, placed upside down on a staging, and one feed-magazine inserted from below, when the gun was fired with as much facility, and the feed worked as well as when placed on top, showing clearly that its action was positive and entirely independent of the force of gravity. No other feed that is known would operate in this manner, and, though this is an exaggerated case, and one not likely to occur in service, yet it shows how effectually the cartridge is held from the time it is placed in the feed-machine to its delivery in the carrier-block, and how impossible for any clogging or overriding to occur, as is the case at times with other feeds.

T. G. BAYLOR,
Lieutenant-Colonel of Ordnance, President of the Board.
GEORGE W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

General S. V. Benét, Chief of Ordnance, United States Army, in his endorsement of the above report, says:

"The great improvement is in the feed, which is positive in its action, and 'entirely independent of the force of gravity.' It is believed that the modified Gatling gun, with the new feed, has about reached the utmost limit of improvement."

Extracts from the official report of the United States Naval Ordnance Board on the trial of the new model, U. S. calibre (0.45-in.) Gatling gun, at the Navy Yard, Washington, D. C., January, 1883:

RAPIDITY OF FIRE.

Five drums (each holding 102 cartridges) to illustrate feed action:
No. 1.—Drum emptied in 2.8 seconds.
No. 2.—Drum emptied in 2.6 seconds.
No. 3.—Drum emptied in 2.8 seconds.

No. 4.—Drum emptied in 2.6 seconds.
No. 5.—Drum emptied in 2.6 seconds.
Number of cartridges expended 510.
The mechanism and feed worked well in each case.
Two trials of eight drums each for rapidity and endurance:
First test—Eight drums emptied in 41.4 seconds.
Second test—Eight drums emptied in 42.2 seconds.
Cartridges expended, 1632.
The mechanism and feed worked well.
A supplemental test was here made with members of the Board at the crank, to determine if it be possible to cause an accidental stoppage or imperfect action in the feed by an irregular or jerking method of turning the crank. Two drums, 204 cartridges, were expended in this manner.
The Board were unable to produce any imperfect action in either mechanism or feed.
One drum at 75 degrees elevation. Expended 102.
Two drums at greatest depression (56 degrees) permitted by the mounting. Expended 204.
Two drums with feed 90 degrees to the right. Expended 204.
Two drums with feed 90 degrees to the left. Expended 204.
Two drums with feed underneath. Expended 204.
Total number of rounds fired, 4014.

W. M. FOLGER,
Lieutenant-Commander and Member.
J. H. DAYTON,
Lieutenant and Member.
F. H. PAINE,
Lieutenant and Member.

It is evident that an accurate vertical fire from Gatling guns, delivering a storm of bullets descending under a slight angle of arrival, would, by grazing the superior crest of parallels erected by besiegers approaching a fortification, or those of ordinary rifle-pits or entrenchments, destroy their occupants much more certainly and rapidly than can be done by the shells or case-shot fired from mortars or field-guns. This "high-angle" or mortar fire from a machine-gun opens up a new field in the science of gunnery, and is well worthy of the highest consideration of military and naval men of all nations.

It is well known that the Turks, in the Russian-Turkish war, inflicted great injury upon the Russian forces at long ranges, by firing their muskets at high elevations, so as to deliver what is known as "high-angle" fire; but it is quite evident that in such firing there must have been a great waste of ammunition, for the reason that the infantry soldiers could not well determine what elevation to give their

muskets in order to have the bullets reach the enemy. This great waste would not take place with the Gatling gun, which, being mounted on a carriage, does not move when being fired. A table of distances and elevations being established for the service of the Gatling gun, all that would be required of the men who use it would be to ascertain first the distance at which the enemy was entrenched, and then to give the gun the required elevation (by the use of the quadrant) in order to have the bullets fall within the line of entrenchments of the enemy. The Gatlings could be protected from the direct fire of the enemy by entrenchments or by a pit dug for each gun, so that not even the muzzle of the gun would be exposed.

Among the prominent advantages claimed for the Gatling gun may be enumerated the following: Its adaptation to the purposes of flank defence at both long and short ranges; its peculiar power for the defence of field-entrenchments and villages; for protecting roads, defiles, and bridges; for covering the crossing of streams; for silencing field-batteries or batteries of position; for increasing the infantry fire at the critical moment of a battle; for supporting field-batteries, and protecting them against cavalry or infantry charges; for covering the retreat of a repulsed column; and, generally, for the accuracy, continuity, and intensity of its fire, and its economy in men for serving, and in animals for transporting, it.

It is conceded that small-calibre Gatling guns, which use the service-musket ammunition, will prove invaluable in naval service when used from top-gallant forecastle, poop-deck, and tops of ships-of-war for firing on an enemy's deck at officers and men exposed to view; for firing down from tops upon the roof of turrets; for firing into an enemy's ports; and, in boat operations against an enemy, either for passing open land-works, or for clearing beaches and other exposed landing-places.

Exhaustive official trials of the gun have been made in many countries, under the supervision of officers of high standing, who have strongly recommended its use, both for land and naval service. The reports of such trials are too extended for a paper of this kind.

Gatling guns have been sold, in greater or less numbers, to most of the governments of the world. A few extracts are given of their use in warfare.

In the late Prussian war, the French used the Gatling gun conjointly with the mitrailleuse. From the London *Journal* we clip a correspondent's description of its efficacious use in action:

Up to this time we had not seen any Prussians, beyond a few skirmishers in the plain, though our battery of Gatlings had kept blazing away at nothing in particular all the while; but now an opportunity of its being in use occurred. A column of troops appeared in the valley below us, coming from the right—a mere dark streak upon the white snow; but no one in the battery could tell whether they were friends or foes, and the commander hesitated about opening fire. But now an aid-de-camp came dashing down the hill with orders for us to pound at them at once—a French journalist having, it seems, discovered them to be enemies, when the general and all his staff were as puzzled as ourselves. Rr-rr-a go our Gatlings, the deadly hail of bullets crashes into the thick of them, and slowly back into the woods the dark mass retires, leaving, however, a trace of black dots upon the white snow behind it. This, their famous and historical four o'clock effort, and its failure, has decided the day. That one discharge was enough.

The Russians used Gatling guns in the siege of Plevna. A special correspondent of the London *Times*, writing under date of November 26, 1877, from the headquarters of the army of Bulgaria, at Bogot, says:

The mitrailleurs [Gatling guns] were in constant action until midnight, splitting the air with their harsh, rattling reports. Another account (November 26th) says: The Russians are using their mitrailleurs [Gatlings] a great deal now at night, probably with the intention of keeping the Turks occupied, so as to relax the tension on the infantry in the trenches.

No other arms in the world are equal to Gatling guns for night service. They can be placed in a position in the daytime so as to cover any point desired, and as they have no recoil to destroy the accuracy of their aim, an incessant fire can be kept up during the night with the same precision as in daytime.

In the naval engagement that took place in Peruvian waters on May 28, 1877, between the Peruvian rebel iron-clad ram Huascar, and the British men-of-war, the Shah and Amethyst, a small Gatling gun, stationed in the foretop of the Shah, rendered excellent service.

The correspondent of the *Illustrated London News*, in a semi-official report of the conflict, says:

About five o'clock, the Huascar being clear of the shoals, we seized the opportunity to close. The enemy likewise closed, with evident signs of ramming, firing shell from her 40-pounder. Our Gatling gun then commenced firing from the foretop, causing the men on her upper-deck quarters to desert their guns.

Captain Aurelio Garcia y Garcia, one of the most distinguished officers of the Peruvian navy, in his account of the above engagement, says:

The firing became even more severe from the English frigates, and, as the distance between the antagonists had been reduced to two cable-lengths, more or less, the Admiral brought to bear all his attacking forces, which, on board the Shah, were very formidable in character. From the tops, a Gatling gun threw a hail of bullets at the decks of the Huascar, together with steady volleys of musketry and rifles.

Another account from Peruvian sources says:

A small Gatling gun stationed in her tops very seriously incommoded the combatants on the ram, and her smoke-stack is riddled with bullets.

It is evident that Gatling guns, when used on shipboard or in tops of war-vessels, would be of inestimable service in firing into the port-holes, or in clearing the decks of the ships of the enemy.

THE NAVAL FIGHT OFF IQUIQUE, PERU.

New York Times, July 20, 1879.

The Huascar attacked us again, directing her bow to the middle of our ship. I steered to prevent the shock, but our want of speed made it impossible, and the iron-clad struck our vessel midships. In that moment, Lieutenant Serrano, followed by a dozen sailors, jumped on the deck of the Huascar, and they were all killed by the shots of musketry and Gatling guns fired from the turret, and behind the parapets of the stern.

THE CHILENO-PERUVIAN WAR.

New York Herald, December 17, 1879.

A letter from Lima, describing the defeat of the Peruvian army, at San Francisco heights, says: "The earthworks were defended by a strong Chilian force, plentifully supplied with Krupp field-pieces and Gatling guns. Here Buendia committed the error which has cost the allies the best division in their army. Instead of making a detour, which he could easily have done, and thus compelling the enemy to descend to attack him in the pampa at the rear of the hill, or submit to having his communications with Pisagua cut off, Buendia gave the order to charge up the rugged hill and carry the works by storm. The attempt was gallantly made. Three times the shattered regiments, which had undertaken a feat which it was impossible to perform, were compelled to fall back and re-form, leaving the hillsides thickly covered with their dead and dying, who had fallen in masses before the Krupps and Gatlings long ere they could make their rifles tell."

THE ZULU WAR.

London Army and Navy Gazette, February 22, 1879.

The Gatling guns, landed with the naval contingent from the Active and Tenedos, have astonished the Zulus, who have been trying an engagement with our blue-jackets. They found the fire much too hot, and the naval force

has had the satisfaction of carrying more than one contested position. It is a pity that Gatlings are not more plentiful with Lord Chelmsford's army. The naval brigade have got some, but the artillery have none. If there had been a couple of Gatlings with the force annihilated the other day, the result of the fight might have been different, for Gatlings are the best of all engines of war to deal with the rush of a dense crowd.

FROM OUR SPECIAL CORRESPONDENT.

London News, August 22, 1882.

I have returned from Chalouf, fourteen miles up the canal, where I witnessed the conclusion of a fight in which 250 men, including the 72d Highlanders, with the blue-jackets and marines from the gunboats Seagull and Mosquito, brilliantly defeated a force of twice their number. The fighting lasted from eleven until nearly five. The Gatling guns, in the tops of the gunboats, worked with admirable precision, doing much execution among the enemy, who had advanced to within 100 yards of the canal-bank.

New York Herald, August 26, 1882.

In a telegram dispatched at 2 o'clock this morning, General Wolseley adds: "I omitted to say that I had with me, yesterday, two Gatling guns, worked by seamen, who did their duty admirably."

London Broad Arrow, September 2, 1882.

On all sides it is acknowledged that the Gatling has proved itself an effective arm of service in the present campaign. At Chalouf, and at Mahuta, the naval Gatling was admirably served by our blue-jackets, and afforded "invaluable assistance." Indeed, it may be broadly affirmed that, in the encounter with the enemy at the former place, the results attained were chiefly ascribable to the action of the Gatlings from the tops of the gunboats Seagull and Mosquito. One hundred and sixty-eight Egyptian soldiers, out of 600 which composed the outpost, were placed *hors de combat.* Under these circumstances, it is not unlikely that Sir Garnet Wolseley will employ Gatling batteries extensively in future operations.

London Army and Navy Gazette, October 14, 1882.

The naval machine-gun battery, consisting of six Gatlings, manned by thirty seamen, reached the position assigned to it in the English lines on September 10th, and, on Tuesday, September 12th, received orders to advance. They came within easy range of the Tel-el-Kebir earthworks, and observed guns in front, guns to the right, guns to the left, and a living line of fire above them. Nothing daunted, the order, "action-front," was given, and was taken up joyously by every gun's crew. Round whisked the Gatlings, r-r-r-r-r-rum! r-r-r-r-r-rum! r-r-r-r-r-rum!—that hellish noise the soldier so much detests in action, not for what it has done, so much as for what it could do, rattled out. The report of the machine-guns, as they rattle away, rings out clearly on the morning air. The parapets are swept. The embrasures are literally plugged with bullets.

The flashes cease to come from them. The Egyptian fire is silenced. With a cheer the blue-jackets double over the dam, and dash over the parapet, only just in time to find their enemy in full retreat. That machine-gun fire was too much for them. Skulking under the parapet were found a few poor devils, too frightened to retire, yet willing enough to stab a Christian, if helpless and wounded. The trenches were full of dead. But few wounded were found. Captain Fitz Roy led his men most gallantly, and followed up the retreating foe until the main camp was reached. Here the halt was sounded. Admiral Sir Beauchamp Seymour and staff now came up and addressed the battery, complimenting the officers and men on their gallantry.

LORD CHARLES BERESFORD ON MACHINE-GUNS.

London Army and Navy Gazette, November 4, 1882.

In my opinion, machine-guns, if properly worked, would decide the fate of a campaign, and would be equally useful ashore or afloat. When the Gatling guns were landed at Alexandria, after the bombardment, the effect of their fire upon the wild mob of fanatic incendiaries and looters was quite extraordinary. These guns were not fired at the people, but a little over their heads, as a massacre would have been the result had the guns been steadily trained on the mob. The rain of bullets, which they heard screaming over their heads, produced a moral effect not easily described. I asked an Egyptian officer, some weeks afterwards, how on earth it was that Arabi, and his 9000 regular troops, who were within five miles, did not march down upon the town in the first four days after the bombardment, when Arabi knew that Captain Fisher's Naval Brigade, which held the lines, numbered less than 400 men. The Egyptian officer replied, "That he knew no army which could face machines which 'pumped lead,' and that as all the gates were defended by such machines, as well as having torpedoes under the bridges, such defences could not be faced." This certainly was the case. I believe the Egyptian officer spoke the truth, and that the moral effect produced by the Gatlings on the people in the first landing prevented the army from attacking the diminutive force which held the lines afterwards.

Replying for "The Navy," at a dinner of the Cutler's Company, Lord Charles Beresford said:

The great value of machine-guns has also been shown. With the Gatlings, the landing parties had cleared the streets of Alexandria and prevented Arabi from returning, and, if they had been allowed to land immediately after the bombardment, they might have dispersed the crowds laden with loot, have captured Arabi, Toalba Pasha, and other leaders, and saved the town; but the government had promised that no man should land, and they were bound by the promise.

Notwithstanding these favorable comments, showing the great value of the Gatling gun in warfare, this distinguished officer, in a paper on

Machine-guns, read before the Royal United Service Institution, Whitehall, London, takes occasion to criticize the Gatling gun, and point out what he claims to be its defects. He says:

> Revolving machine-guns are excellent in their way, and we owe the father of them, Dr. Gatling, a great deal for his valuable invention, but their principle invites an accident; they have to do five things nearly simultaneously, any one of which by going the least bit wrong interferes with the other four, and the gun is instantly out of action. The five things are:—revolving the lever, revolving the barrels, loading the gun, withdrawing the empty cylinder, firing the gun—all to be done nearly simultaneously.

Now the casual observer would hardly suppose that all machine-guns have to do substantially the "five things" spoken of; for instance, the Nordenfeldt gun has to have the lever moved forward, which moves the breech supports towards the barrel chambers, which push the cartridges in front of them; then the breech is locked, the cartridges fired, the lever moved backward, the breech unlocked, and the fired cartridge-cases extracted by the retiring breech-plugs—all of which "things," or movements, have to be done quickly in order to obtain rapidity of fire, whereas the simple movement of revolving the crank loads and fires the Gatling gun.

There are several valuable features of the Gatling gun that should not be overlooked; for instance, a ten-barrel Gatling gun fires ten times in one revolution of the group of the barrels. The action of each part is therefore quite deliberate, while collectively the discharges are frequent. Another valuable feature in the Gatling is, that the cartridges are fed into the carrier at the top, and are carried around to the under side of the gun before they are loaded and fired. Thus, it will be seen, the point where the cartridges are fired is far removed from the supply of cartridges used in feeding the gun, so there is no liability of the escape of gas, which may occur by the bursting of the head of a cartridge, and which might communicate with the magazine, causing a dangerous explosion. Most other machine-guns have their magazines, used for feeding cartridges to them, placed in close contact with the firing-point, hence the liability of premature and dangerous explosions. Several accidents of this kind have occurred, resulting in death to the operators of such guns.

The Gatling gun is dangerous only to those in its front.

Sir Garnet Wolseley, in discussing the subject of machine-guns, has expressed his conviction that the general, who, in the next big war, utilizes machine-guns to the best advantage, will have an immense opportunity to gain great fame.

Machine-guns are closely allied to metallic cartridges, which are of modern invention. Without the latter, the former would be of little use.

The art of making metallic cartridges is now so well-understood that they work perfectly, and their use makes the machine-gun of immense practical value.

The French mitrailleur did not use metallic cartridges. It used paper-cased cartridges, which were imperfectly made, and this fact, coupled with the imperfection and great weight of the gun, together with want of skill in its use, led to its failure.

The same class of men who doubted that rifle-guns would ever take the place of the smoothbore, and who declared that the breech-loading musket would never supersede the muzzle-loader, object to machine-guns. Their objections are, that such guns are liable to get out of order, and to become disarranged, by means of a hostile shot, lack of care, ignorance in management, or from similar causes, etc.

Without defending machine-guns in general from these objections, it may be said that the simplicity of parts in the Gatling gun, the protection given to the working mechanism, and its absolute working, make it as secure from accident as any gun can well be, even if it be worked only by brawny hands.

A trial of a 0.50-inch calibre Gatling gun (old model) was made at Fort Madison, Maryland, in October, 1873, under the supervision of the late Lieutenant-Commander J. D. Marvin, U. S. N.; during the trial 100,000 cartridges were fired, and of this number 63,600 were fired without stopping to wipe out or clean the barrels. The Official Report says:

"The working of the gun throughout this severe trial was eminently satisfactory, no derangements of any importance whatever occurring."

Surely, such a severe test should prove that the Gatling gun is not liable to get out of order.

The value of an invention is to be determined by the results it can accomplish. The Gatling can fire more shots in the same space of time than any other gun. With it, three men can do the work of hundreds armed with ordinary guns. Its use will, to a great extent, supersede the necessity of large armies; hence its use will be in the interests of economy.

It is evident that in the future wars are to be waged with all the aids that modern science can afford, whether they are the results of the

discoveries of chemists, or of the inventions of mechanics. The record of wars and isolated engagements in which the Gatling gun has borne an important part within the last fifteen years, is sufficient to establish the value of machinery in warfare, and the superiority of the gun over the ordinary individual arm.

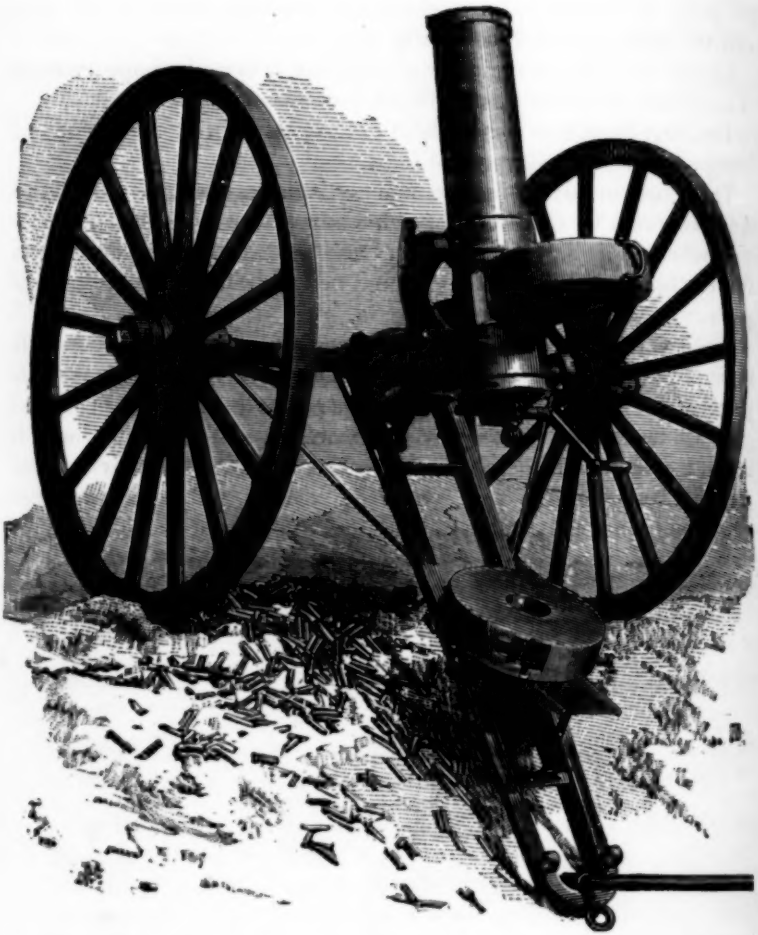
History furnishes abundant evidence that it is to the improvement of arms that nations have owed their successes in war.

The First Napoleon was enabled to conquer most of the nations of Europe by the use of improved guns.

The Prussian army, in like manner, was enabled to defeat the Austrian forces by the use of breech-loading "needle-guns."

It behooves all nations to furnish their soldiers with the best arms that can be procured, and they should be taught their use in times of peace.

Intelligent men, who have carefully watched and noticed the march of improvement, and the steady development of new ideas, will perceive and acknowledge that the day is not far distant when machine-guns will be extensively employed in warfare; and the nation which is best supplied with them, and which best understands their tactical use, will best preserve the lives of its soldiers, and be in the best condition to make favorable treaties, and to preserve the integrity of its own dominions.



The above illust ation represents the Gatling gun, with its improved feed, in position to deliver high-angle or mortar fire.

DISCUSSION.

THE CHAIRMAN.—This most interesting subject is now open for discussion, and members of the Institute and others are invited to present to the meeting their views upon the points suggested by the lecturer. Officers of the army present are cordially requested to take part in the discussion. Attention is especially invited to the somewhat novel feature (as applied to machine-guns) of *high-angle* fire.

Without presuming to add greatly to the interesting lecture of the distinguished inventor, I would beg to note that he has not mentioned all the good points apparent in the present development of the Gatling system; and he has modestly abstained from special reference to its adaptability to naval uses.

A statement of the principles that demanded the changes resulting in the present improved feed would have been much more interesting coming from the inventor himself, but I may perhaps be pardoned in making a hasty reference to them. This I shall do in view of their importance, and also in view of the logical manner in which certain grave defects in the system have probably been definitely eliminated.

It is clear that a machine-gun is almost worthless if not reliable; if not ready at all times for instant use, if ever unready. In an action on shore, a machine-gun that has *jammed*, as the expression goes, is a captured gun, if unsupported by others; the enemy well knows that if he does not charge he cannot take it, as its sustained fire is irresistible. Afloat, certainty of action at a given moment will be, if possible, even more important than on shore, as the use of a small-arm calibre piece will be limited to the cases of emergency of a close action between ships, to offensive and defensive auxiliary employment in ramming, and to defence against a torpedo attack by boats. Failure at such times might be disastrous.

The original feed, as you all probably remember, depended upon gravity alone for its action. The cartridges were *dropped* into a hopper, in the earliest model, falling undirected through a considerable interval. This first feed was a single vertical column of cartridges, similar to the tin case used until within a few months. It was found to be defective, in that accidental stoppages occurred, and that it contained too small an amount of ammunition to sustain a fire for any length of time. An Austrian officer suggested the drum feed (so called from its shape), which carried a number of columns of cartridges, each of which was in turn brought opposite the hopper, the whole drum being turned either by the revolving carrier or by hand. This feed corrected the defect of insufficient quantity; but the action, as before, depending on gravity, there were as frequent stoppages as in the earlier feed, and in order to relieve the gun the heavy drum had to be first removed.

The feed was again changed to a single column of cartridges, placed over the axis of the piece, and as near the bottom of the carrier as possible, in order that the fall of the cartridge might be reduced to a minimum. The perform-

ance of the gun was improved, but the old difficulty was still present. There was at any moment a liability to jam, which destroyed confidence in the gun. It might fail at a vital instant; and, as usually occurs, it probably would so fail.

The problem of overcoming this difficulty was by no means a simple one, and some of the best inventive talent of all lands was concentrated upon it. Nobel, Gorloff and Baranovsky in Russia, Hotchkiss and Broadwell, to say nothing of a score of clever mechanical minds in this country (among whom should be named Bruce of the Springfield Arsenal), have all attempted a solution.

The desideratum was: A magazine (susceptible of being quickly charged, and containing such a number of cartridges that while the weight loaded would not be too great for ready handling, it would still be sufficient for an effective salvo) which should possess such mechanical features that, while grasping each cartridge firmly to prevent movement in any but a desired direction, the cartridge would be guided along a given path, ending at the carrier, preserving its parallelism to the latter throughout the journey. Thus a *positive* action, as it is termed technically, would be gained, *in spite of gravity, if necessary*.

After years of practical experience and study, the present feed was proposed by Mr. George Accles, the firing expert of the Gatling Company. It has withstood the tests of many official trials in this country and abroad, and has, it would appear, corrected the most serious defect in the Gatling system, thereby, in all probability, quadrupling its value. The feed is simply a wheel, actuated by the revolving carrier, carrying the charge of (100) cartridges around in a spiral groove in the enclosing cylinder ends; the groove holds heads and points against movement in any direction but its own, and ends as a tangent to the revolving carrier, where the cartridges are successively, and without possibility of derangement, deposited for the action of the plunger-locks.

The method of filling these magazines (a feature nearly as important as the rapid delivery itself, since, the supply of prepared ammunition exhausted, the gun becomes useless) is ingenious, but is a natural consequence of their own mode of action. The test of feeding up against gravity with the feed under the gun, referred to by the lecturer, suggested this feature to a clever mechanic at Colt's (Mr. Goodall). It was to utilize the revolving feature of the gun in order to feed the feed. A crank turns a toothed wheel, which in turn revolves the feed-wheel in a direction reverse to that in delivery upon the gun, the cartridges being stripped into a flange-way grooving above, from the usual packing cases. In this manner there is given a rapidity in filling cases about equal to the delivery of fire of most of the rival systems of machine-guns, and, with a moderate supply of filled cases to begin with, the fire may be rendered continuous for the limited period of naval action emergencies, or for the duration of the critical moment of an engagement on shore.

I do not think the office of machine-guns of the calibre of the Gatling extends farther than this. Artillery of much greater power in range and accuracy will always hold its place in the *feeling* stage of an engagement, and in giving the hard knocks. The importance of machine-guns for this special purpose, however, is hardly contestable, even though the failures of the French with an imperfect weapon prejudiced the military world for a time against them.

It seems, too, in considering their employment on board ship, where the question of transportation of ammunition is somewhat secondary, that the effectiveness of machine-guns will increase with the number of shots per minute of delivery of fire. If within range, the greater the delivery, the more demoralizing will be the effect upon an enemy, whether he be charging, standing his ground, or retreating. In this the Gatling system stands quite alone. Its delivery is undeniably greater than that of its rivals.

The question also frequently arises as to the relative merits of the volley and the continuous fire. With our usually unsteady platform, I think most naval men will agree that the chances of damaging the enemy are greater with the continuous fire. The delivery should, however, in my opinion, be made in salvos of thirty shots each, or three turns of the crank, if the piece be used afloat, as the jet of balls would be greatly dispersed with a longer effort.

A very serious feature of machine-gun fire is the production of smoke, which is unavoidable with rapid delivery; frequently three turns are all that can be made before the target is obscured; therefore, captains should strive for the weather-gage.

Gun-servants should be carefully instructed in the proper method of delivering Gatling fire. The crankman soon finds with practice that there is a position where the least output of work on his part will accomplish the object; and it is fortunate that this result of least labor corresponds to the best performance of the gun.

The leverman or pointer should be taught the principles of wing-shooting, as here he not only has a moving enemy, but is unstable himself, and he delivers a stream of projectiles of which only a portion may be effective.

Although the inventor of the Gatling system feels that the present gun is nearly a finality in development, it seems as if we were likely, in the not very distant future, to hear of progress, if not in mechanical features or rapidity in delivery, at least in ballistics. Machine-guns are now shielded with steel aprons, which, like all else in the direction of armor, must be pierced by the gun. It is not improbable that we shall hear ere long of *high-power* musket calibre machine-guns, using charges equal in weight to one half that of the projectile, and steel or steel-cased bullets. I think we should hear of such guns now.

Rear-Admiral C. R. P. Rodgers.—It seems to me, Mr. Chairman, that a subject as interesting as this is should be fully discussed at a meeting where so many, both of the Army and Navy, high in authority in matters relating to ordnance, are present.

To us who began long ago the profession of arms upon the sea, when nothing could be brought into action effectively except the heavy guns with which our ships were armed, it seems immensely important, now that we have arms of precision, that machine-guns should be brought prominently forward in naval actions that are to take place hereafter.

I happened to serve not very long ago in the Pacific, where, between certain ironclads, Peruvian and Chilian, and between unarmored ships and ironclads,

several engagements that attracted the attention of the world took place. No one cognizant of the facts could doubt for a moment the immense advantage gained by the Chilians in filling their tops with riflemen armed with breech-loading guns. In these encounters, as the ships approached each other, it became impossible, on the uncovered decks, for men to stand to their guns. They were driven time and again to shelter, and those of us who observed the engagements could but remark how greatly exposed those gunners were, and how terrific was the fire to which they were subjected.

In the English and French ships of war, and our own, then in the Pacific, the men at their guns were much exposed to this fire from an enemy's tops. This was especially the case in the smaller French ships, whose pivot-guns were unusually high. The Shannon, a superb English ironclad, carried most of her battery exposed to this fire; and with machine-guns and well-trained riflemen in an enemy's tops, the gunners of the Shannon could have stood to their guns only with great loss of life and a great strain upon the steadiness of their aim.

I had no thought of taking part in this discussion, but the very interesting and valuable statement of our chairman was followed by a long silence, and I have spoken simply to break the ice, and to induce the distinguished ordnance officers now present, to favor us with their views.

BRIGADIER-GENERAL S. V. BENÉT, U. S. A.—I certainly shall not attempt to add anything to what has been said by my old friend, Dr. Gatling, in his lecture, nor to what has been so well and appropriately said by the Chairman of this meeting. The fact is I am wholly in accord with everything that has been stated on this subject, and I will therefore only give you a few historical recollections. I believe I was the first officer of our services that had any connection with the Gatling gun. The year of the termination of the war, 1865, I knew nothing of this gun and had never seen it. Dr. Gatling, its now distinguished inventor, came to the Frankford Arsenal, where I was then in command, with the Gatling gun, which I was instructed by the Chief of Ordnance to inspect and improve if possible. I remember that it was a very crude affair, for I recollect particularly that the Doctor told me he had first got a cartridge and then built the gun around it, and it seemed to be so. I can say of him also that he had but little idea of the science of gunnery at that time, and I attempted during the several months that he remained with me to teach him the little that I knew. I am very happy to say that the pupil has far outrun his teacher. Very soon after my attention was called to the gun I found that there was one thing which was absolutely necessary to do to insure its success, and that was to make it a central-fire gun. The gun was of one-inch calibre, adapted to that famous cartridge around which he had built the gun. The cartridge had a folded head with rim-fire. It had in its rim three grains of percussion powder, and every time it was fired there was danger of injury to the cartridge, if not of destruction to the gun. This was about the infancy of the manufacture of metallic cartridges in this country. As you all know, metallic cartridges are at the best very troublesome things to make. During the war the rim-fire cartridges

were principally used, and especially with the Spencer guns. The idea of a centre-fire cartridge had been broached and experimented with, and I remember telling Dr. Gatling that the success of his gun depended very largely on his changing it to a centre-fire. He demurred, and we had quite a number of discussions upon the subject; but, finally, I was able to convince him. With many misgivings he decided that he would attempt to make the change, and certainly the result was most creditable to his mechanical and inventive faculty. Within forty-eight hours he brought me a drawing of a new centre-fire lock, and I presume that the principle involved in that lock, made nearly twenty years ago, will be found in the present perfected gun. After worrying over the subject for several months and doing the best I could with it, I finally recommended to the Chief of Ordnance that the gun should be sent to Fortress Monroe, to be examined and reported upon by disinterested parties. The result was that the report was so favorable that Secretary Stanton at once gave an order for the purchase of a hundred of these guns, fifty of which were to be of one-inch calibre and the other fifty of half-inch calibre. That was the first boost that the Gatling gun received. Since that time I have been a strong advocate of machine-guns, and I have used whatever influence I have possessed in getting appropriations for their construction and in having them issued to the army. Through the influence of Colonel Williston of the 2d Artillery, who has probably more practical knowledge in the use of the gun than any other man in the army, the interest felt in machine-guns has been largely increased. Upon my recommendation, General Sherman had Williston's battery, which is one of the ten in the Artillery service, made into a battery of machine-guns, and I believe at my suggestion that General Sherman had that battery sent to the School of Application at Fort Leavenworth, in order to be able to prove by practical tests whether the machine-gun is not a proper weapon to be used in connection with infantry and cavalry in active service.

I do not know that I have anything further to say, but I am very sure that Dr. Gatling is the father of machine-guns. I believe the use of the Gatling gun will become a permanent and prominent feature in our military system and an important factor in future wars. A large portion of the credit for the introduction of such arms is undoubtedly due to my old friend, Dr. Gatling.

COMMANDER W. S. SCHLEY.—In regard to the high-angle fire suggestion, an idea presents itself to my mind with regard to the inaccuracy of such a system, and the impracticability and difficulty of ascertaining the range that attends its use.

If we introduce an explosive shell, the fire of a shower of projectiles will accomplish the results sought. The conditions under which high-angle fire would fail appear to me to be when no definite range could be determined. If explosive shell were used, the piece would be fired certainly with much better effect. So far as high-angle fire is concerned it is not a matter of much importance. On board ship we generally elevate the piece into tops and fire at low angles down upon decks; consequently, the rifle-bullet would answer our purpose; but if the Gatling is to be used for general purposes in naval

warfare, it would seem to me to be necessary to adopt explosive shells similar in weight and penetrative power to those used in Nordenfeldt or Hotchkiss guns. At present the Gatling has only a special use—that connected with the shore operations of naval forces; but, I think, if it is to maintain its place in our armaments, it must have its calibre increased so as to give it effective power against torpedo boats as well as against men simply. I merely suggest these points in the hope of drawing out further discussion on these interesting questions.

DOCTOR R. J. GATLING.—In England they have "range-finders" and other means by which distances can be determined with greater accuracy, I think, than can be done by the explosion of shells fired from field-guns. Be that as it may, when men become entrenched, there will be time to ascertain how far the enemy is from you. You could get up near enough in the night to place your Gatling guns in pits or under cover, and then give the guns proper elevation by the use of a quadrant, so as to have the bullets discharged fall on men behind the entrenchments. The bullets so discharged descend nearly perpendicularly, and strike the ground with a force sufficient to penetrate two or three inches of timber. In this way men can be killed behind entrenchments—thus making such positions untenable.

These are points that I am glad have been brought forward in this discussion, as their consideration will be useful.

I have witnessed a great deal of shell firing from field-guns, both in this country and in Europe, and in my opinion it is difficult to determine accurately the distance of an object by such firing. To the eye, the shells seem to burst just in front of a target or near the object, when, in truth, they burst far short of the target or object fired at. I have seen field-guns fired at targets at one thousand yards range, and the shells seemed to explode in front of the target, and I have imagined that the target was riddled with missiles; but when the target was examined, a few hits only were noted. In such instances the shells had exploded before reaching the proper point in front of the target. I have witnessed some trials in target practice with field-guns, in competitive trials with the Gatling gun, where the number of hits of the former were so few as to be unworthy of note.

A competitive trial took place at Shoeburyness, England, between 9-pounder and 12-pounder English field-guns, and 1-inch, 0.65- and 0.42-inch calibre Gatling guns, Colonel Wray (now General) conducting the trials. Targets placed at various distances from the guns, as far as 2070 yards range, were fired at, and although the Gatling guns used on that occasion were not nearly so perfect and effective as the improved Gatlings now made, they hit the targets oftener at all ranges than the field-guns, which greatly astonished the members of the committee. General Wray, in his report of these trials, states that a Gatling gun is equal to three field-guns in effective killing power, up to sixteen hundred yards. And he further says, one battery of Gatling guns will take up only about one-fourth of the road space required for a battery of 9-pounder field-guns.

I wish to say, Mr. President, a few words about my friend, General Benét. He is very kind in his remarks, and I am glad to see that his memory is so clear as to our experiences at the Frankford Arsenal. I was worrying over the rim-fire cartridge. The trouble was that the heads of such cartridges were liable to burst and come off when fired, and I had no device that would extract the balance of the shells remaining in the chamber of the barrels. The General put me on the right track. "I would surely," said he, "change the cartridge to a centre-fire," *and he insisted upon it.* To make such change would involve some time and expense, and I was in a great hurry to get the gun into practical shape and general use, but he overcame every argument that I could bring forward and insisted on his idea of centre-fire. That centre-fire cartridge belongs to him, and was the first one made. He is justly entitled to the credit of his suggestion, and the perfect working of the gun to-day arises in a great degree from the adoption of the centre-fire and the metallic cartridge. It is with pleasure I give him the credit due him. I thank the General for his remarks, as they will greatly aid in preserving the history of the gun and cartridge.

The Gatling gun is the original arm of its class, and whatever merit there is in it belongs to the United States.

It is with pleasure I state that our own government has recognized the importance of this gun, and has given it a place in the field, in its forts, and on its ships. But it is stating only the truth when I say that the leading foreign governments have recognized the true worth of this gun, and that they are to-day better armed with it than our own government.

REAR-ADMIRAL C. R. P. RODGERS.—I would like to ask a question as to the penetrating power of the Gatling gun when used in this way against steel-clad torpedo boats.

THE CHAIRMAN.—Torpedo boats, as they are built at present with steel-plates, cannot be penetrated by the fire of the Gatling gun. They can be penetrated by the projectiles of machine-guns of a larger calibre.

COMMANDER W. S. SCHLEY.—In the discussion of this matter of machine-guns, and their general introduction into the service of various nations, the object in view has been to obtain a gun that would be effectual as a torpedo-arrester; it therefore seems to me that the Gatling gun, if it is to be of general use to us, should be adapted not only for infantry operations on shore, but also for naval operations, such, for instance, as preventing the placing of torpedoes. If it fails therefore to penetrate, it must of necessity give way to guns that will penetrate. The Hotchkiss, for example, and the Nordenfeldt, have the penetrating power, and they make use of it most effectually. At the battle of Alexandria it was a noticeable feature of the battle that the machine-guns, such as the Gatling, were not within range. No bullets from these guns were found in the two days' fight at that place, whereas balls fired by the Nordenfeldt guns were picked up on the beach. I believe that some of the prisoners of the English stated in a conversation with some of the English officers that their defeat

was entirely due to the screeching of the shells over their heads. If the Gatling guns that were used in the engagement had been actively used, as it appears they were, and discharged at the rate of 1000 a minute, it seems to me very strange that some balls were not found on the battle-field, if the guns accomplished the purpose intended, as did other guns in use at the time.

DOCTOR R. J. GATLING.—I will say in reply to the remarks just made, that my lecture would have been too long, had I taken up and discussed the merits of both the larger and smaller size calibre guns. I have therefore confined myself to the smaller calibre guns, which are light and effective, and well adapted for service in our navy, and for warfare of any kind.

Gatling guns can be, and are, made of large calibre. The 1-inch Gatling discharges half-pound balls, and has a range of over two and a half miles; but such guns are heavier than the musket calibre Gatlings, which are light and easily handled, and which have a range of 3500 yards.

In the bombardment of the forts at Alexandria recently, by the English, Commander Schley says he has seen it stated that, although Gatling guns of the small calibre were used by the ships of the attacking fleet, it was a curious fact that none of the balls from these guns could be found anywhere near the battle-field. To that statement I desire to say that I have had extended correspondence with gentlemen who were present when these naval engagements took place in front of Alexandria. I am informed that some persons assert that not only were no bullets found that had been fired from the Gatling guns, but that there were none of any kind to be found that were fired from the Nordenfeldt guns, which were also used in the action.

This is explained in this way: The bullets, fired from the ships at some distance, and coming down with considerable force, would naturally and necessarily sink in the earth. Especially would this most likely be so where the soil is sandy and loose, and where little pressure is required to sink anything in the ground. Then again, after the bombardment was over, before the English forces landed, the Egyptian soldiers and pillagers visited the battle-ground to see if anything of value was left, and it is not at all unlikely that, if any bullets had been in sight (which I think very improbable in view of the facts I have just stated) that these people would have collected them and carried them off as relics.

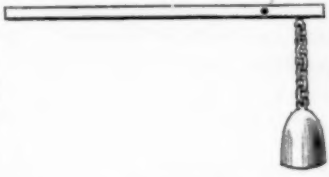
It is a fact, however, worthy of note that the Gatling gun is highly spoken of by the English officers who have used it, and who are in a position to know its merits as a weapon of war.

I do not think the English have adopted or purchased any Hotchkiss guns. My information is that the English on that occasion used no other machine-guns than the Gatling and the Nordenfeldt.

LIEUTENANT R. F. NICHOLSON.—I should like to ask the Chair if any experiments have been made in this country with the view of developing the power of small arms in the direction he referred to in his remarks.

THE CHAIRMAN.—A few experiments have been made at the Experimental Battery by direction of the Bureau of Ordnance, Navy Department, with a .50 calibre Remington rifle, old model, using considerably heavier charges than usual, in a longer chamber, and modifying the character of the powder grain. The results were quite satisfactory, a velocity of 1880 feet being obtained with 185 grains of powder and 450 of lead, without undue distress in recoil. The energy of a musket calibre bullet possessing such a high velocity was illustrated in the impact upon an iron plate one inch in thickness, against which the bullet was fired. Although the bullet was of lead, the indent was three-eighths of an inch in depth by one inch in diameter.

LIEUTENANT-COLONEL JAS. M. WHITTEMORE, U. S. A.—With the introduction of the positive feed to the Gatling machine-gun, two kinds of high-angle fire are made effective. These may be classed as direct and indirect: direct, when the gun is aimed at the object; indirect, when the bullets are fired up in the air, in order to hit the object in their fall. The direct fire should be used when practicable, as it is the more destructive and saves time in its death-dealing mission. To protect men on the spar-decks of ships-of-war from the deadly effect of the fire of machine-guns, the exposed parts ought to be bullet-proof, either permanently or temporarily. Iron shields, hinged at the sides of the deck to fold down upon it when not in use, might answer a good purpose. When required to shield the men they could be raised to an angle of about forty-five degrees and supported by struts; they would form a very good sloping protection from bullets; when hit by large projectiles they would stand a chance of being knocked down as well as knocked to pieces. They could be balanced at any angle by chains and weights attached near the hinge and running to the lower deck. When raised, they should be so arranged that if struck by heavy shot they would not be knocked down upon the deck, thereby possibly crushing men behind them. This could be done with bolsters. When folded down, they would assist in protecting the deck from indirect high-angle fire. These high-angle fires, made effective by the positive feed, increase the power of the gun as an important weapon for the suppression of riots. Mounted upon a movable platform on rollers, protected by shields, and pushed along from the rear, buildings and streets could be cleared with little exposure to the men manœuvring the gun. A platform could have two guns mounted upon it; one to clear the streets and the first stories of houses, the other to clear upper stories and roofs by direct and indirect high-angle fire.



THE CHAIRMAN.—In resuming the discussion, the Chair begs to note particularly the point raised by the Chief of Ordnance on the necessity for reliability in the ammunition for guns of the class in question.

No system of machine-guns can furnish even an acceptable performance with bad ammunition. In spite of the various plans for eliminating the disadvantages of burst cartridge shells, a cessation of the fire is the result of such an accident, with a delay more or less long, dependent generally upon the coolness of the operators. Many of the failures in official trials have been due solely to the ammunition. In this connection we have in this country great reason to congratulate ourselves upon the present high development in excellence of the U. S. cartridge as manufactured at the Frankford Arsenal.

The question of high-angle fire is extremely interesting, and it may develop even afloat, where its usefulness would at first seem to be limited, into a feature of considerable importance.

We can all recollect many cases during the Civil War, particularly in river service between high, overhanging banks, where high-angle fire would have been an effective factor. An opportunity for testing its value was also presented in the Corean expedition. Moreover, it will be useful at low angles in repelling an enemy close aboard.

With regard to its accuracy at high angles, there will doubtless be much to wish for. The projectiles at the great altitude reached where motion of translation and rotation nearly ceases are greatly affected by even a very light breeze, and except in calm weather a range-table would be of slight utility. A further disadvantage in correcting the range, as suggested in the remarks of Commander Schley, is found in the very slight disturbance of the surface of the water by the fall of musket calibre projectiles fired at high angles. There is, perhaps, no disturbance at all on land.

In conclusion, the Chair begs to tender the thanks of the meeting to the lecturer for his interesting essay, and also to the officers of the Army for their participation in the discussion.

PROFESSIONAL NOTES.

AIR-REFRIGERATING MACHINE.

Reprinted from a Report made to the Bureau of Steam Engineering by a Board composed of the following officers: Chief Engineer B. F. ISHERWOOD, *U. S. N.; Chief Engineer* THEODORE ZELLER, *U. S. N.; Chief Engineer* ROBERT DANBY, *U. S. N.* April 6, 1883.

The subject of this report is the air-refrigerating machine devised by S. B. Hunt, and submitted by him in November, 1879, to the Navy Department for examination of its capability to ventilate completely the entire interior of naval vessels with cool dry air, for the purpose of increasing the health and comfort of the *personnel* therein embarked, to enable fresh meat and vegetables to be carried for long periods, and to enhance the durability of the vessels, if constructed of wood.

Of the Board of Naval Officers appointed to make this examination, Chief Engineer Charles E. De Valin was a member. He devised and conducted the experiment hereinafter described, and took all the necessary data during its progress, with the intention of making it the subject of a special report to the Bureau, as such an experiment was not within the purview of the Board; but, his intention being frustrated by orders to sea, he gave his notes to the undersigned, who used their data in the present investigation, made the required calculations, and submit the results in the belief they will be found of permanent value. The subject is not only of considerable engineering interest, but is certain to frequently recur, and the undersigned do not know of any other experiment with an air-refrigerating machine in which complete and accurate data were taken.

The special object of the machine in question, and for which alone it was designed, is to furnish dry air of very low temperature, to be delivered into an air-tight chamber, constructed with non-heat-conducting floor, ceiling, and sides. A constant, but very slow current of the refrigerated air circulates through and out of this chamber by means of a small outlet pipe in the ceiling, fitted with a valve. The circulation is just sufficient to maintain the desired low temperature by the replacement of air that may become too much heated, by freshly refrigerated air. Of course, the quantity required of the latter, per unit of time, depends on the atmospheric temperature and on the more or less non-conductibility of the material of which the chamber is built. This chamber is used for the storage of fresh meat to be preserved for very long periods from putrefaction. Notably, this is an important employment of the system on board transoceanic steamers freighted with fresh meat for a market in foreign ports. The dryness of the refrigerated air is a very valuable factor in this connection, as air of a low temperature, if containing much moisture, is unsuited for the purpose, the meat becoming mildewed after short exposure in it. The proper temperature for the chamber is found to be a few degrees above the freezing point. It is not desirable to freeze the meat, but only to keep its temperature sufficiently low to prevent decomposition.

The machine on which the experiment was made is a permanent fixture in the large market at the Hudson river end of West Thirty-fourth street, New York

City, where the refrigerated chamber is successfully used for the storage of fresh meat or other articles of food requiring a low temperature of dry air for their preservation.

The refrigeration of the air is produced by a purely mechanical method, in conformity with the mechanical theory of heat; no chemicals are employed, and the atmospheric air is the only substance operated on. The air is first compressed in a cylinder to a convenient degree by a steam engine, and its heat of compression due to the work performed upon it, extracted by subjecting it in pipes exposing sufficient surface for the purpose to the external air, or to water, or to both, until its temperature falls to that of the atmosphere, the pressure being meanwhile maintained by the steam engine. Then the compressed air is admitted to a cylinder in which it acts expansively upon a piston and does work, the pressure of the expanding air being always equal to the resistance against which it acts, and for every 789¼ foot-pounds of work performed by the expanding air one Fahrenheit unit of its contained heat is extracted, this quantity of heat being transmuted into that quantity of work. Finally, the air thus refrigerated is delivered into the chamber where its low temperature and the dryness resulting from that lowness are to be utilized. Of course, instead of being exhausted into a relatively small chamber, the refrigerated air could be distributed by proper pipes and registers through the apartments of a vessel, which would thus undoubtedly be supplied with air of low temperature to any extent that the required space and weight could be allowed for the refrigerating machine, for the fuel needed for its steam engine, and for the distributing pipes.

The following is a description of the machine.

REFRIGERATING MACHINE.

The machine is composed, first, of a non-condensing, unjacketed, horizontal steam cylinder, in which power is developed in the usual way from steam supplied by a boiler. This cylinder has no expansion valve. The steam valve is the ordinary three-ported slide without lap, so that the steam is worked without expansion from the beginning to the end of the stroke of the piston. The power is graduated by an ordinary butterfly throttle-valve, placed in the steam pipe near the cylinder, and controlled by an ordinary governor. The steam valve has neither steam lead nor exhaust lead. The steam could not be used in a more wasteful and unskilful manner for the production of power. This, however, does not affect either the efficiency or the economy of the system, as nothing prevents the employment of an engine of the most improved type. The cylinder is 14 inches in diameter, with 12 inches stroke of piston. The piston is attached directly to a horizontal main shaft whose axis is at right angles to the axis of the cylinder, by means of the usual piston-rod, crosshead working between guides, and connecting-rod articulated to the crank-pin of a single crank.

Next, the steam power is employed to work duplicate air-compressing cylinders, both of which are horizontal and single-acting, with their axes in the same horizontal plane as the axis of the steam cylinder. The two air-compressing cylinders are in horizontal extension of each other, the pistons of both being keyed to the same piston-rod, so that these two single-acting cylinders are equivalent to one double-acting cylinder of the diameter and piston stroke of either. The steam cylinder and the compressing cylinders lie side by side, with but a narrow space between them. The pistons of the air-compressing cylinders are worked directly from the pin of a pair of cranks on the main shaft through a connecting-rod, crosshead between guides and piston-rod. The diameter of the air-compressing cylinders is 12 inches, and the stroke of their pistons is 9 inches. One end of these cylinders has no cover, but is left open to the atmosphere, while the other end is closed by a single disk-valve of

the same diameter as the cylinders, moving horizontally on a guide, opening outwards, and performing the functions of an air-delivery valve. At the centre of this disk-valve is another and very much smaller one, opening inwards, moving horizontally on a guide, and performing the functions of an air-receiving valve; through it the compressing cylinders are filled with air of atmospheric pressure, which, after being compressed to the maximum tension, is expelled through the delivery valve into a long pipe that connects the two compressing cylinders with the air-expanding cylinder to be hereafter described. The compressing cylinders have no clearance, and no passage between them and the seats of their valves. Their pistons advance to the extreme ends of their cylinders, whose delivery valves open before the pistons reach the termination of their stroke. During the experiment hereinafter described the air in the compressing cylinders received its maximum tension when the pistons of those cylinders had performed the 0.778 of their stroke; then the delivery valves opened, and the tension remained the same during the remaining 0.222 of the stroke of the pistons, the compressing pistons compressing the air in the cylinders throughout that 0.222 of their stroke, and throughout the pipe connecting the air-compressing cylinders with the air-expanding cylinder, which air was undergoing continuous decrease of bulk by external cooling from the opening of the air-delivery valve of the compressing cylinders to the opening of the air-receiving valve of the air-expanding cylinder, this continuous decrease of bulk being compensated by the corresponding continuous compression, so that the tension of the air remained nearly constant. This tension would have been constant but for the resistance of the inner surface of the connecting pipe, and of its bends to the movement of the air, which resistance caused the pressure to continuously decrease in the pipe from its compressing cylinder end to its expanding cylinder end, and, in addition to thus maintaining at nearly constant pressure the continuously decreasing bulk of air throughout the latter 0.222 of their stroke, and throughout the connecting pipe between the compressing and expanding cylinders, the compressing pistons drive the piston of the air-expanding cylinder through the portion of its stroke performed before the expansion valve on that cylinder closes; consequently, the power exerted by the piston of the air-expanding cylinder before its cut-off valve closes, though developed in that cylinder, is directly developed by the pistons of the air-compressing cylinders.

The compressing cylinders, with the exception of their ends, were water-jacketed, the water circulating through the jackets being obtained without cost of power from the Croton mains supplying New York City with potable water. The jacket space of each cylinder was 1⅛ inches wide and 14½ inches long. The top of the jacket of each cylinder was open to the air, and presented a level surface of water 15 inches wide and 14½ inches long, from which evaporation was continually taking place. These water-jackets were greatly insufficient to take up the heat of compression; the temperature of the water when entering them was 55 degrees Fahrenheit, and when leaving them 118 degrees. The initial temperature of the compressed air was 60 degrees Fahrenheit, and its temperature when leaving the compressing cylinders was 280 degrees Fahrenheit.

The compressing cylinders being situated close beside the steam cylinder, and taking in their air through a vertical pipe of 3½ inches internal diameter, whose open top was 4 feet 4 inches above those cylinders, received air heated by the radiation from the steam cylinder and its steam pipe, and from the open water-surface of the jackets, so that it was heated (60°—55°=) 5 degrees above the general temperature of the air near the floor of the room containing the machine. The temperature of the atmosphere outside the building was about 40 degrees Fahrenheit.

The pipe connecting the two air-compressing cylinders with the air-expanding cylinder was of wrought iron, and had many bends or returns in order that it might be compactly arranged. In addition to its use for conveying the com-

pressed air from the former to the latter, its surface was employed to reduce the temperature of that air from the 280 degrees Fahrenheit which it had on entering the pipe to the 56 degrees which it had on leaving the pipe to enter the expanding cylinder; and this cooling was accomplished by exposing part of the surface of the pipe to the air outside of the room containing the machine, but inside the building containing that room, and the remaining part to water constantly flowing through a tank placed on the floor of the room and supplied from the Croton mains, with a temperature of 55 degrees Fahrenheit, which was maintained in the tank.

The pipe from the air-compressing cylinders to the tank had, for the length of 22 feet, an outside diameter of 1⅞ inches, and an inside diameter of 1.69 inches, and, for the remaining length of 270 feet, an outside diameter of 2⅜ inches and an inside diameter of 2.65 inches. The aggregate outside surface of this pipe was 214.02150 square feet, and its aggregate inside surface was 197.05162 square feet. The pipe immersed in the tank (in direct continuation of the preceding, the two forming one pipe) was 156 feet long, 1½ inches in outside diameter and 1.33 inches in inside diameter, exposing to the water an outside surface of 61.26120 square feet, and an inside surface of 54.31826 square feet. The pipe from the tank to the air-expanding cylinder (in direct continuation of the preceding and forming with them one pipe) was 20 feet long, 1⅞ inches in outside diameter and 1.69 inches in inside diameter, exposing to the air of the lower portion of the room containing the machine an outside surface of 9.81750 square feet, and an inside surface of 8.84884 square feet.

All these pipes were continuous and had their interiors in common. They were distributed in lengths returned upon each other for economy of space, like the pipes of ordinary steam-heaters. From the compressing cylinders a length of pipe rose vertically to a convenient height; thence the remaining pipe was nearly horizontal, being arranged with a slight and uniform inclination to the expanding cylinder, in order to drain whatever water might be deposited from the compressed air as it cooled.

The pipe surface, measured on the outside, exposed first to the air, was 214.02150 square feet, and measured on the inside was 197.05162 square feet, and that air had the temperature of 45 degrees Fahrenheit. Then a surface of 61.26120 square feet, measured on the outside of the pipe, and of 54.31826 square feet, measured on the inside, was immersed in the water of the tank, which water entered the tank with the temperature of 50.6 degrees Fahrenheit, and left it with the temperature of 55.2 degrees. Finally, the remaining 9.81750 square feet of pipe surface, measured on the outside, and 8.84884 square feet, measured on the inside, were exposed to air of 55 degrees Fahrenheit temperature in the lower portion of the room containing the machine.

The lowest depression of the pipe was just at its entrance into the expanding cylinder, and at that point a water-trap was placed, which delivered the water of deposition from the pipe as fast as it accumulated, and thereby prevented its entrance into the expanding cylinder. Had this water entered the expanding cylinder, the low temperature existing there would have congealed it into very hard ice, whose mechanical obstruction would have rendered the working of the machine impossible. This trap is an absolutely essential part of the air-refrigerating system, which could not be reduced to practice without it.

There is one horizontal double-acting air-expanding cylinder of 5¼ inches diameter, with 9 inches stroke of piston. Its axis is in the same horizontal plane as the axes of the steam cylinder and compressing cylinders, and it lies on the outer side of the compressing cylinders, so that the latter are between it and the steam cylinder. The piston of the expanding cylinder is connected directly to the crank-pin of a single crank on the main shaft, through the usual piston-rod, crosshead between guides, and connecting-rod. The air-expanding cylinder is fitted at each end with two poppet valves worked by cams. One valve, adjustable at will, is for the admission of the compressed air from the pipe, and it closes when any desired fraction of the stroke of the piston has

been completed, thus acting as the expansion valve as well as the admission valve of the air. The other valve is for exhausting the air from the cylinder; it opens when the piston has completed the air stroke, and remains open during the exhaust stroke. The air in the cylinder had neither lead nor cushion. The area of the port at each end of the cylinder was 1 square inch.

The portion of the stroke of the piston of the air-expanding cylinder performed while the expansion valve was open was done by the pressure of the air-compressing pistons through the medium of the air in the connecting pipe; the air for this portion of the stroke was therefore used absolutely without expansion. For the remaining portion of the stroke the piston of the air-expanding cylinder was driven entirely by the expansion of the air admitted during the first portion of the stroke; and all the refrigeration below the general temperature of the air in the room containing the machine was produced after the closing of the expansion valve by this expansion of the air in its performance of work upon the main shaft. The air entered the expanding cylinder at the temperature of 56 degrees Fahrenheit, and left it with the temperature of —57 degrees, making a total fall of temperature of 113 degrees Fahrenheit. All the power developed in the air-expanding cylinder was expended on the compression of air in the two air-compressing cylinders.

The steam cylinder, the two air-compressing cylinders, and the air-expanding cylinder are situated side by side on the same bed-plate, and had their axes in the same horizontal plane. They were all connected directly to the same main shaft, which extended clear across one end of the bed-plate. The compressing cylinders were between the steam cylinder and the expanding cylinder, so that the whole formed a compact arrangement, occupying a space 10 feet 4 inches long, 6 feet 7 inches wide, and 4 feet 9 inches high.

The space occupied by the water-tank was additional to the above, and was 13 feet long, 21 inches wide, and 11 inches high. The water from this tank was carried to the water-jackets of the compressing cylinders, and thence discharged.

The space occupied in the air by the pipe connecting the compressing and expanding cylinders was still more additional.

The chamber to be refrigerated was constructed with double floor, ceiling and sides of pine boards, and the intervening space was filled with sawdust. This chamber should have no inleakages of air, no outleakages except through the proper delivery, and its floor, ceiling, and sides should be as little heat-conducting as possible. The capacity of the chamber was 11,419 cubic feet, equivalent to the capacity of a cube whose sides are 22.519 feet. The chamber had near its top a hole of ¼-inch diameter, through which the air delivered by the expanding cylinder escaped into the atmosphere. The pressure in the refrigerated chamber was slightly greater than that of the atmosphere, so that any leakages must have been outward. The barometer in the chamber stood at 30.240 inches, and outside the chamber at 30.106 inches.

The exhaust pipe from the expanding cylinder to the refrigerated chamber was 12½ feet long, and had the outside diameter of 4 inches. It was exposed to an air-temperature on its outside of 56 degrees Fahrenheit. It entered the chamber at the height of 7 feet 5 inches above the floor. The ¼-inch diameter hole by which the air left the chamber was 9 feet above the floor.

The following are the dimensions of the principal working parts of the refrigerating machine:

STEAM-CYLINDER.

Number of steam-cylinders	1
Diameter of steam-cylinder	14 inches.
Diameter of piston-rod	1⅛ inches.
Stroke of steam piston	12 inches.
Net area of piston, exclusive of rod	152.4644 square inches.
Space displacement of piston per stroke	1.058785 cubic foot.

Space in clearance and steam passage at one end of cylinder	0.118215 cubic foot.
Area of steam-cylinder port (10 inches by 0.6 inch)	6 square inches.
Diameter of exhaust pipe (outside)	3 inches.
Length of exhaust pipe	59 feet.
Number of right angles in exhaust pipe	5
Length of crank-shaft or main shaft	67 inches.
Diameter of crank-shaft journals	3⅞ inches.
Length of crank-pin journal	3½ inches.
Diameter of crank-pin journal	2¼ inches.
Length of connecting-rod between centres	42 inches.
Diameter of connecting-rod at crosshead neck	1⅝ inches.
Diameter of connecting-rod at crank-pin neck	2⅜ inches.
Number of fly-wheels on main shaft (one on each side of compressing cylinders)	2
Outside diameter of fly-wheels	47½ inches.
Breadth of rim of fly-wheels	4 inches.
Depth of rim of fly-wheels	4½ inches.

AIR-COMPRESSING CYLINDERS.

Number of air-compressing cylinders (single-acting)	2
Diameter of air-compressing cylinders	12 inches.
Diameter of piston-rod (no rod at the side of piston used)	2⅜ inches.
Stroke of the pistons	9 inches.
Area of one compressing piston	113.0976 square inches.
Space displacement of one compressing piston per stroke	0.58905 cubic foot.
There is no clearance nor passage to valves.	
Number of connecting-rods	2
Length of connecting-rods between centres	53⅞ inches.
Diameter of connecting-rod at crosshead neck	1⅜ inches.
Diameter of connecting-rod at crank-pin neck	2½ inches.
Diameter of crank-pin journal	2¾ inches.
Length of crank-pin journal	3½ inches.

AIR-EXPANDING CYLINDER.

Number of air-expanding cylinders (double-acting)	1
Diameter of air-expanding cylinder	5½ inches.
Diameter of piston-rod	1½ inches.
Stroke of piston of air-expanding cylinder	9 inches.
Net area of piston, exclusive of rod	20.76395 square inches.
Space displacement of piston per stroke	0.1081456 cubic foot.
Space in clearance and steam passage at one end of cylinder	0.cc60081 cubic foot.
Area of cylinder port	1 square inch.
Length of connecting-rod between centres	45⅜ inches.
Diameter of connecting-rod at crosshead neck	1⅜ inches.
Diameter of connecting-rod at crank-pin neck	2¼ inches.
Diameter of crank-pin journal	2¾ inches.
Length of crank-pin journal	3½ inches.

SPACE OCCUPIED.

Bulk of the entire refrigerating machine, with the exception of the space occupied by the pipe exposing 285 square feet of outside surface and connecting the air-compressing and the air-expanding cylinders, in its various convolutions to obtain from external air and water the necessary cooling for the air within	323.132 cubic feet.
Side of a cube having the capacity of 323.132 cubic ft.	6.862 feet.

PROPORTIONS.

Cubic feet of capacity of steam-cylinder per cubic foot of capacity of air-compressing cylinders	1.79744
Cubic feet of capacity of steam-cylinder per cubic foot of capacity of air-expanding cylinder	9.79037
Cubic feet of capacity of air-expanding cylinder per cubic foot of capacity of air-compressing cylinders	0.18359
Aggregate cubic feet of capacity in both steam-cylinder and air-expanding cylinder per cubic foot of capacity of air-compressing cylinders	1.98104

BOILER.

The steam cylinder was supplied from one boiler having horizontal flues in direct continuation of the furnaces with horizontal tubes returning above the flues and furnaces. There was no steam chimney or other means for superheating the steam; but there was over the centre of the boiler a cylindrical steam drum or reservoir, from the top of which the steam pipe proceeded to the steam cylinder. This pipe was 321 feet long, 3 inches in inside diameter, and had nine right-angled bends. The front portion of the boiler was rectangular in plan, with a semicircular top. The back portion was cylindrical and its upper half was a horizontal extension of the semicylindrical top of the front portion. The following are the principal dimensions and proportions of the boiler, namely:

Extreme length of boiler	13 feet.
Extreme breadth of front portion of boiler	7 feet 3 inches.
Extreme diameter of back portion of boiler	7 feet 3 inches.
Extreme height of boiler exclusive of steam-drum	9 feet.
Height of steam-drum above top of boiler	4 feet.
Diameter of steam-drum	3 feet 6 inches.
Number of furnaces	2.
Breadth of furnace	3 feet.
Length of grate bars	6 feet.
Total area of grate surface	36 square feet..
Number of flues (three from each furnace)	6.
Inside diameter of flues, four of 11½ inches and two of 17 inches.	
Length of flues	4 feet.
Number of tubes (iron)	72.
Outside diameter of tubes	3¾ inches.
Inside diameter of tubes	3¼ inches.
Length of tubes	8 feet 6 inches.
Diameter of chimney	2 feet 4 inches.
Height of chimney above level of grate bars	47 feet 6 inches.
Area of heating surface in the flues	83.776 square feet.
Area of heating surface in the tubes, calculated for their inside circumference	520.730 square feet.
Area of all other heating surface	251.494 square feet.
Total area of heating surface	856.000 square feet.
Cross-area of the flues for draught	6.038 square feet.
Cross-area of the tubes for draught	4.148 square feet.
Cross-area of the chimney	4.276 square feet.
Square feet of heating surface per square foot of grate surface	23.778
Square feet of grate surface per square foot of cross-area of flues	5.962
Square feet of grate surface per square foot of cross-area of tubes	8.679
Square feet of grate surface per square foot of cross-area of chimney	8.419

The boiler and steam pipe were thoroughly protected from heat radiation by felt and lagging. The feed water was taken from the mains of the Croton Aqueduct, in which the pressure was so great that scarcely any expenditure of power was required to do the feeding.

THE EXPERIMENT.

With the refrigerating machine as described, an experiment was made on the 18th of November, 1879, of eight hours and fifty-five minutes, consecutively, duration. Indicators were placed permanently on the steam cylinder, on the air-compressing cylinders, and on the air-expanding cylinder, from each end of all which an indicator diagram was taken every half hour; eighteen complete sets of diagrams were thus taken during the experiments and equi-spaced over it. The results hereinafter given are the means of all these diagrams.

The variation in the steam pressure (controlled by a governor), and in the revolutions of the main shaft (equalized by two heavy fly-wheels), were so slight that the mean results from the diagrams may be taken to represent accurately the mean performance for the whole time.

The number of revolutions made by the main shaft was taken by a counter.

Compared thermometers were permanently hung so as to give the temperature of the air in the market building outside of the chamber containing the refrigerating machine, the general temperature of the air in that chamber, and the local temperature of the air entering the compressing cylinders. Two thermometers were permanently inserted in the pipe connecting the compressing and expanding cylinders, one being placed as close as possible to the air-compressing cylinders so as to give the temperature of the compressed air when leaving them, and the other being placed as close as possible to the air-expanding cylinder so as to give the temperature of the compressed air when entering it. Two other thermometers were permanently inserted in the exhaust pipe of the air-expanding cylinder, one as close to that cylinder as possible to give the temperature of the air leaving it, the other as close as possible to the refrigerated chamber to give the temperature of the air entering it. This exhaust pipe connects the air-expanding cylinder with the refrigerated chamber. A thermometer was placed in the refrigerated chamber 18 inches from the end of the exhaust pipe of the air-expanding cylinder, in order to obtain the temperature of the refrigerated air after it had spread that short distance into the chamber. Another thermometer was so hung as to give the general temperature of the air in the refrigerated chamber. And still another was hung to give the temperature of the air as it left this chamber. The temperature of the water from the Croton mains, used for feeding the boiler and supplying the cooling tank and water-jackets, was also given by permanently placed thermometers, which showed the temperatures of this water when entering and leaving the tank and when entering and leaving the jackets.

Compared barometers were placed in the chamber containing the refrigerating machine and in the chamber refrigerated, to show the difference of pressure in them.

Pressure gauges were permanently inserted into the boiler; into the steam pipe near the steam cylinder, but on the boiler side of the throttle-valve; into the pipe connecting the air-compressing and air-expanding cylinders at the point where the compressed air leaves the former, and at the point where the same air enters the latter.

All the water passing through the tank and through the water-jackets was measured. This quantity is the same for both tank and jackets, the water being led from the former through the latter. All the water discharged from the water-trap placed in the lowest point of the connecting pipe close to its entrance into the air-expanding cylinder, was measured. The temperature of this water, on emerging, was the same as that of the compressed air at the same place.

All of the above quantities were observed every half hour and entered in the columns of a tabular record. The means of these columns will be found below.

The coal consumed was Pennsylvania anthracite of good quality. It was carefully weighed, as was also its refuse in ash, clinker, and dust.

The following are the means of the entire performance, the quantities being arranged in groups for facility of reference:

STEAM-CYLINDER.

ENGINE.

Steam pressure in the boiler, in pounds per square inch above the atmosphere	60.
Steam pressure in the steam-pipe near the cylinder, on the boiler side of the throttle-valve, in pounds per square inch above the atmosphere	47.
Atmospheric pressure in the chamber containing the refrigerating machine in pounds per square inch	14.778
Temperature of the feed water, in degrees Fahrenheit	50.6
Temperature, in degrees Fahrenheit, of the air in the chamber containing the refrigerating machine	55.
Number of double strokes made per minute by the steam piston	143.875

NOTE.—The steam was not cut off by either independent expansion valve or by steam lap on the steam valve. The steam was neither cushioned nor released before the end of the stroke.

STEAM PRESSURES IN THE CYLINDER PER INDICATOR.

Steam pressure on the piston in pounds per square inch above zero, at the commencement of its stroke	60.
Steam pressure on the piston in pounds per square inch above zero, at the end of its stroke	53.
Mean back pressure against the piston in pounds per square inch above zero	25.770
Minimum back pressure against the piston in pounds per square inch above zero, at commencement of its stroke	16.780
Indicated pressure on the piston in pounds per square inch	28.912
Net pressure on the piston in pounds per square inch, applied to air compression	26.751
Total pressure on the piston in pounds per square inch	54.682

HORSES-POWER.

Indicated horses-power developed by the steam piston	38.4369
Net horses-power developed by the steam piston applied to air compression	35.5641
Total horses-power developed by the steam piston, calculated to zero	72.6966

RATE OF COMBUSTION.

Pounds of anthracite consumed per hour	297.0841
Pounds of combustible, or gasifiable portion of the anthracite, consumed per hour	247.5701
Per centum of the anthracite in refuse of ash, clinker, and dust	$16\frac{2}{3}$
Pounds of anthracite consumed per hour per square foot of grate surface	8.2523
Pounds of combustible consumed per hour per square foot of grate surface	6.8769
Pounds of anthracite consumed per hour per square foot of heating surface	0.3471
Pounds of combustible consumed per hour per square foot of heating surface	0.2892

ECONOMIC RESULTS.

Pounds of anthracite consumed per hour per indicated horse-power	7.7291
Pounds of anthracite consumed per hour per net horse-power.....	8.3535
Pounds of anthracite consumed per hour per total horse-power.....	4.0866
Pounds of combustible consumed per hour per indicated horse-power	6.4409
Pounds of combustible consumed per hour per net horse-power....	6.9612
Pounds of combustible consumed per hour per total horse-power...	3.4055

WEIGHT OF STEAM ACCOUNTED FOR PER HOUR IN THE CYLINDER.

Pounds weight of steam present per hour in the cylinder at the end of the stroke of its piston, calculated from the pressure there....	2546.7407
Pounds weight of steam of the pressure at the end of the stroke of the piston, theoretically required per hour for the total horses-power developed by the steam piston, including the steam in the clearances and steam passages of the cylinder, and supposing the steam to be used without expansion.....	2522.9467

AIR-COMPRESSING CYLINDERS.

TEMPERATURES.

Temperature, in degrees Fahrenheit, of the external atmosphere	40.
Temperature, in degrees Fahrenheit, of the air in the market building outside the room containing the refrigerating machine	45.
Temperature, in degrees Fahrenheit, of the air in the room containing the refrigerating machine.....	55.
Temperature, in degrees Fahrenheit, of the air when it enters the compressing cylinders.....	60.
Temperature, in degrees Fahrenheit, of the air when it leaves the compressing cylinders...	280.
Number of Fahrenheit degrees of temperature imparted to the air in the compressing cylinders by compression.....	220.

PRESSURES.

Pressure of the atmosphere in pounds per square inch above zero	14.778
Mean pressure of the air in the compressing cylinders during the indraught stroke of their pistons, in pounds per square inch above zero, per indicator.....	14.778
Maximum pressure of the air in the compressing cylinders, in pounds per square inch above zero, per indicator.....	142.100
Pressure of the compressed air in the pipe immediately on leaving the compressing cylinders in pounds per square inch above zero, per gauge.....	140.515
Mean indicated pressure of the compressed air against the pistons of the compressing cylinders, in pounds per square inch above the atmosphere.....	55.060
Fraction of the stroke of the pistons of the compressing cylinders completed when the maximum air compression is obtained and the delivery valve opened	0.778
Mean pressure in pounds per square inch above the atmosphere, of the air in the compressing cylinders while being compressed during the 0.778 of the stroke of their pistons from the commencement, per indicator.....	34.440

HORSES-POWER.

Indicated horses-power exerted on the pistons of the compressing cylinders	40.7242
Horses-power exerted on the pistons of the compressing cylinders during the 0.778 of their stroke from the commencement, while the air was being compressed to the maximum pressure, per indicator	19.8180

UNITS OF HEAT ACCOUNTED FOR.

Pounds of water flowing per hour through the water-jackets of the compressing cylinders to cool their contained air	800.
Temperature, in degrees Fahrenheit, of the cooling water when it enters the water-jackets of the compressing cylinders	55.
Temperature, in degrees Fahrenheit, of the cooling water when it leaves the water-jackets of the compressing cylinders	118.
Number of Fahrenheit degrees imparted to the cooling water in the water-jackets of the compressing cylinders	63.
Number of Fahrenheit units of heat taken per hour out of the air in the compressing cylinders by the cooling water flowing through their water-jackets	50497.240
Pounds of natural air compressed per hour in the compressing cylinders	756.166
Number of Fahrenheit units of heat shown by thermometer to have been imparted per hour to the air compressed by the compressing cylinders, on leaving the latter	39626.123
Total number of Fahrenheit units of heat accounted for per hour, being the sum of the number in the cooling water from the jackets and in the air compressed by the compressing cylinders	90123.363
Number of Fahrenheit units of heat per hour equivalent to the horses-power expended in the compression of the air	102165.241
Number of Fahrenheit units of heat per hour dissipated by radiation from the surfaces of the compressing cylinders into the atmosphere	12041.878
Per centum of the Fahrenheit units of heat per hour equivalent to the horses-power expended in the compression of the air, dissipated by radiation from the surfaces of the compressing cylinders	10.001

AIR-EXPANDING CYLINDER.

TEMPERATURES.

Temperature, in degrees Fahrenheit, of the air entering the expanding cylinder	56.
Temperature, in degrees Fahrenheit, of the air leaving the expanding cylinder	—57.
Number of Fahrenheit degrees of temperature lost by the air in the expanding cylinder	113.

PRESSURES.

Pressure of the air in the pipe immediately before entering the air-expanding cylinder, in pounds per square inch above zero	136.78
Maximum air pressure on the piston of the air-expanding cylinder before the closing of the cut-off valve, in pounds per square inch above zero	93.00
Air pressure on the piston of the air-expanding cylinder at the closing of the cut-off valve, in pounds per square inch above zero,	87.00

Air pressure on the piston of the air-expanding cylinder at the end of its stroke, in pounds per square inch above zero	30.87
Mean back pressure against the piston of the air-expanding cylinder, in pounds per square inch above zero	16.83
Minimum back pressure against the piston of the air-expanding cylinder (at the commencement of its stroke) in pounds per square inch above zero	16.25
Indicated air pressure on the piston of the air-expanding cylinder, in pounds per square inch	39.67
Net air pressure on the piston of the air-expanding cylinder applied to air compression, in pounds per square inch	38.00
Total air pressure on the piston of the air-expanding cylinder, in pounds per square inch above zero	56.50
Fraction completed of the stroke of the piston of the air-expanding cylinder, when the cut-off valve closed	0.228
Number of times the air was expanded in the air-expanding cylinder,	3.72257
Mean pressure of the expanding air in the air-expanding cylinder after the closing of the cut-off valve, in pounds per square inch above zero	46.00

HORSES-POWER.

Indicated horses-power developed by the air-expanding cylinder	5.38685
Net horses-power developed by the air-expanding cylinder applied to air compression	5.16008
Total horses-power developed by the air-expanding cylinder	5.66549
Total horses-power developed in the air-expanding cylinder by the expanding steam after the closing of the cut-off valve	3.27304
Pounds of water collected per hour by the trap just in advance of the air-expanding cylinder	2.456

UNITS OF HEAT ACCOUNTED FOR.

Pounds of natural air discharged per hour from the air-expanding cylinder into the refrigerated chamber	368.806
Number of Fahrenheit units of heat per hour taken out of the air discharged from the air-expanding cylinder into the refrigerated chamber	10278.4019
Number of Fahrenheit units of heat per hour equivalent to the total horses-power developed in the air-expanding cylinder by the expanded air alone after the closing of the cut-off valve	8211.1109
Number of Fahrenheit units of heat per hour equivalent to the horses-power developed by the air during its expulsion of itself from the air-expanding cylinder into the refrigerated chamber after the opening of the exhaust valve	2067.2910

REFRIGERATED CHAMBER.

Pressure of the external atmosphere, in inches of mercury	30.1063
Pressure of the air in the refrigerated chamber, in inches of mercury,	30.2416
Temperature, in degrees Fahrenheit, of the air in the refrigerated chamber	39.

REMARKS.

For the calculations on air in the foregoing table, its specific heat is taken at 0.2382, which is the mean of the independent determinations made by Regnault and by Weidemann, the specific heat of an equal weight of water at the temperature of 32 degrees Fahrenheit being taken as unity.

The air, when drawn into the air-compressing cylinders, is supposed to contain a quantity of aqueous vapor equal to three-fourths of what it could contain at its temperature if saturated, and when discharged from the air-expanding cylinder it is supposed to contain one-third of the quantity of aqueous vapor it held when it was drawn into the air-compressing cylinders, the remaining two-thirds having been deposited as water in the pipe connecting the air-compressing and air-expanding cylinders, from which pipe this water was trapped out before the air entered the air-expanding cylinder. The weight of aqueous vapor contained in a cubic foot of natural air under the experimental conditions of temperature and pressure was taken from Regnault's hygrometric tables, and his weight of chemical air per cubic foot, that is, of air exclusive of aqueous vapor and carbonic acid gas, was modified in accordance with the assumed quantities of aqueous vapor with which it was mixed.

The coefficient of the expansion or contraction of air under constant pressure is taken to be 0.00204 of the air's bulk at the temperature of 32 degrees Fahrenheit for each added or subtracted Fahrenheit degree of temperature.

The Fahrenheit unit of heat is the quantity of heat required to raise the temperature of one pound of water from 32 to 33 degrees Fahrenheit under the standard atmospheric pressure.

The mechanical equivalent of one Fahrenheit unit of heat is taken to be 789¼ foot-pounds, and as one-horse power is 33,000 pounds raised one foot high per minute, the thermal equivalent of one-horse power is $\left(\frac{33,000}{789\frac{1}{4}} = \right)$ 41.811847 Fahrenheit units of heat, which number, multiplied by the number of horses-power developed, and by 60—the number of minutes in an hour—will give the number of Fahrenheit units of heat equivalent to the mechanical work performed by the horses-power during an hour.

The number of Fahrenheit units of heat in a given number of pounds of air between two Fahrenheit temperatures is found by multiplying the number of pounds of air by the number of degrees between the two temperatures and by 0.2382.

In calculating the number of Fahrenheit units of heat imparted to the cooling water supplied to the jackets of the air-compressing cylinders, the difference in the specific heat of the water at the entering and at the leaving temperature was included.

The total horses-power exerted by the steam cylinder is calculated for the mean pressure on the piston taken down to the zero line or line of no pressure, and this mean pressure is the sum of the mean indicated pressure and of the mean back pressure on the piston during its stroke. The total horses-power, therefore, expresses the entire mechanical work of the steam; for, overcoming the back pressure against the piston is as much mechanical work as overcoming any other resistance.

The indicated horses-power is that portion of the total horses-power which is employed in doing the commercial work required and in overcoming the frictions of the machine, the commercial work in the present case being the compression of air.

The net horses-power is what remains of the indicated horses-power after subtracting the horses-power absorbed by all the various frictions of the machine. This is the power which is employed wholly in compressing air—that is, in doing commercial work.

In the air-compressing cylinders and in the air-expanding cylinder, all the operations are above the atmospheric pressure, that pressure, in fact, representing for those cylinders the zero line or lowest limit of pressure, because the air compressed or expanded had already the atmospheric pressure before these operations were performed upon it. The indicated pressure is, of course, the mean pressure as given by the indicator diagram. For the air-compressing cylinders there is neither net pressure nor total pressure, as the atmospheric pressure is the back pressure, and as the indicated pressure is entirely exerted

in the compression of the air. For the air-expanding cylinder the total pressure is the indicated pressure plus the difference between the atmospheric pressure and the back pressure, this difference being caused by the too restricted opening and by the sinuous passage for the escape of the expanded air at the end of the stroke of the piston of the air-expanding cylinder. The net pressure is what remains of the indicated pressure after subtraction of the pressure required to work the air-expanding cylinder *per se*.

If the compressed air entered the air-expanding cylinder at its pressure in the valve-chest of that cylinder, and maintained this pressure until the cut-off valve closed, then the total horses-power developed by the expanding air alone in the air-expanding cylinder, to the performance of which work the refrigeration of the air is entirely due, would be calculated for the mean pressure of the expanding air after the closing of the cut-off valve, taken down to the atmospheric pressure line, as, overcoming the back pressure above that line is as much doing work as overcoming any other resistance. Of course, this mean pressure only acts for the portion of the stroke of the piston which remains after the closing of the cut-off valve. Again, if the compressed air in the air-expanding cylinder, instead of being expanded down to the atmospheric pressure, have, at the end of its expansion, a pressure greater than that of the atmosphere, it will, when discharged into the atmosphere, do work upon and heat the latter, experiencing itself a refrigeration equivalent to the work thus done; and this refrigeration will be additional to what is due to the work of expansion done upon the piston of the air-expanding cylinder.

This distribution of the power developed is absolutely necessary to an understanding of the processes of the air-refrigerating machine, and to a correct appreciation of its economic performance. Without such distribution there cannot be ascertained how much of the practically possible has been achieved, the causes of the limitations, and the reasons why the performance should be as it is experimentally found to be, thus reconciling the theoretical predictions with the results practically obtained.

During the process of compressing the air, heat will be generated in it equal to the thermal equivalent of the work of compression, and this heat, by expanding the air, will increase its resistance to compression; consequently, such heat should be extracted as fast as generated, so that the compressed air, when at the maximum compression desired in the compressing cylinder, should have only the atmospheric temperature. To wholly effect this, when the entire compression is done by a single operation in one compressing cylinder, may not be possible with the means at command, but the nearer the approximation the nearer perfection is the result. The means adopted in the experimental machine was to water-jacket the air-compressing cylinder, and, if the surface in the jacket could be made large enough relatively to the weight and temperature of the air within the cylinder, and to the quantity and temperature of the water practicable to be passed through the jacket per unit of time, then the desired cooling of the compressed air to the atmospheric temperature would be accomplished. The largest water-jacket surface will be obtained by giving the air-compressing cylinder the smallest diameter and the longest stroke of piston practicable. The air-compressing cylinder must of necessity be single acting, and its material might be bronze, which has a much greater heat-conducting capacity than cast iron. During the experiment, the water for the jackets was taken from the pipes supplying New York City with potable water under a pressure of over 50 pounds per square inch above the atmosphere, so that a very large quantity could be had without trouble and without expenditure of power by the machine; but in many locations, this water could only be obtained by a special expenditure of power for that purpose.

The area of water-jacket surface, relatively to a given weight of air to be compressed to a given tension in a given time, could be increased with a given stroke of piston, by distributing the space displacement of piston per stroke required into several air-compressing cylinders of proportionally reduced

diameter. The most effective method, however, of keeping the air in the compressing cylinder at the atmospheric temperature during the process of compression, is to conduct that process successively in several cylinders of decreasing capacities; the more numerous the succeeding cylinders, the more completely will the end be accomplished.

The first cylinder of the series must be of sufficient capacity in connection with the number of strokes made by its piston in a given time, to receive the desired amount of air of atmospheric pressure to be operated with in that time, but the compression is to be carried in this cylinder to only a fraction of the final compression; consequently, the heat generated in this cylinder will be only the relatively small quantity due to the smallness of the compression, and this small quantity can be taken out of the air as fast as produced by the water of the jacket.

From the first cylinder the partially compressed air having the atmospheric temperature is delivered into the second cylinder of the series, which has as much less capacity than the first as the final pressure in the first is greater than the initial pressure. In this second cylinder the air is still more compressed, but not to a greater tension than the water-jacket is capable of keeping at the atmospheric temperature during the compression.

From the second cylinder the air at the maximum tension received in it, but having the atmospheric temperature, is delivered into the third cylinder of the series, which has as much less capacity than the second as the final pressure in the second exceeds the initial pressure there; and in this third cylinder the air is still more compressed, but not to a tension exceeding that from which the water-jacket will extract the heat of compression as fast as generated; and so on, until the desired maximum pressure is reached.

This system is only a mechanical device for increasing the area in the water-jacket to the extent that will enable the water to absorb the heat of compression as rapidly as produced, so as to maintain the air in the air-compressing cylinders during the entire process of compression at the atmospheric temperature. Should the water-jackets, with a reasonable number of air-compressing cylinders, not prove sufficient to maintain the air undergoing compression, at the atmospheric temperature, that air, in its passage from one cylinder to the next, can be conducted through a coil of pipe immersed in a tank supplied with water, and the necessary cooling surface be thus obtained. Indeed, if the air, in its passage from one compressing cylinder to the next, be conducted through a sufficient length of pipe not immersed in water, but exposed to only the atmosphere, it is obvious that the temperature of the air undergoing compression may be kept during that process nearly down to the atmospheric temperature, and by this means an air-refrigerating machine might be successfully operated without water. The question is evidently simply one of surface of pipe.

In calculating the heat of compression for the experimental machine, the indicated horse-power given by diagrams taken from the air-compressing cylinders, is the measure of the work of compression; that is to say, the horse-power computed from the mean pressure above that of the atmosphere during the compression for the entire stroke of the pistons of the air-compressing cylinders.

That the resistance due to the heat of compression is wholly detrimental is evident from the consideration that the weight of atmospheric air taken in by the air-compressing cylinders during their indraught stroke of piston is a fixed quantity, and that—no air leakage being supposed—this same quantity at the same atmospheric temperature enters the air-expanding cylinder, the heat of compression having been taken out of the air after it left the compressing cylinders and before it entered the expanding cylinder, so that the air-expanding cylinder will develop precisely the same power, let there be no heat of compression in the compressing cylinders or much. The power developed by the expanding cylinder has a fixed proportion to that developed in the compressing

cylinders only when the temperature of the air is constant throughout. All the power developed in the air-compressing cylinders caused by the expansion of the air therein, due to the heat of compression, is entirely lost; hence the desirability of maintaining the air during compression at the atmospheric temperature, which allows the machine to be operated for a given quantity of refrigeration with the minimum of power so far as the compression of the air is concerned.

In the case of the experiments the air was received by the compressing cylinders at the pressure of 14.778 pounds per square inch above zero, and compressed to 142.100 pounds per square inch above zero, the compression being 9.615645 times. The mean total pressure against the pistons of the compressing cylinders was 69.838 pounds per square inch above zero, or 55.060 pounds per square inch above the atmosphere, and the heat of compression in the compressing cylinders was very great. Now, had that heat been extracted from the air as fast as generated, the mean total pressure against the pistons of the compressing cylinders would have been only 48.2738 pounds per square inch above zero, or 33.4958 pounds per square inch above the atmosphere, between the same limits of pressure, namely, 14.778 and 142.100 pounds per square inch above zero; and the horses-power expended in compressing the air would have been only 24.7746 instead of 40.7242, the experimental number; consequently, by reason of the heat of compression in the air within the compressing cylinder, there was required $\left(\frac{40.7242 - 24.7746 \times 100}{24.7746} =\right) 64.3788$ per centum more power for effecting the same compression than if that heat had been taken out of the air as rapidly as generated, so as to preserve the temperature of the air undergoing compression constant throughout the entire process.

The temperature of the compressed air when leaving the compressing cylinders was 280 degrees Fahrenheit. This was the mean temperature for the whole mass of air delivered per stroke of the compressing pistons, but the maximum temperature within the compressing cylinders was considerably higher, and occurred at the point where compression reached its maximum, namely, when 0.778 of the stroke of the compressing pistons was accomplished and the delivery valve opened.

The air, with 60 degrees Fahrenheit of temperature and 14.778 pounds per square inch above zero of pressure, undergoing compression, had its temperature remained constant, would, when compressed into $(1.000 - 0.778 =) 0.222$ of its original bulk, have had the pressure of $\left(\frac{14.778}{0.222} =\right) 66.568$ pounds per square inch above zero, so that in order to raise its pressure under constant volume to 142.100 pounds per square inch above zero, which it experimentally had at the point where maximum compression was reached, its temperature must have been raised by the compression to 658.45 degrees Fahrenheit, because $\frac{142.100}{66.568} = 2.1347$, and, taking the pressure of the air at 32 degrees Fahrenheit as unity, its pressure at 60 degrees will be 1.06712, and at 658.45 degrees 2.277958, and $\frac{2.277958}{1.06712} = 2.1347$. Consequently, $(658.45 - 280.00 =) 378.45$ Fahrenheit degrees of temperature were extracted from the compressed air in the compressing cylinders by the water of their jackets during the last 0.222 of the stroke of their pistons.

From the air-compressing cylinders, the compressed air is carried in a pipe to the air-expanding cylinder in which the refrigeration below the atmospheric temperature is to be effected, and, as it is absolutely necessary to the production of the maximum refrigeration that the compressed air should enter the air-expanding cylinder with a temperature not above that of the atmosphere, whatever residual heat it may contain above that temperature when leaving the air-compressed cylinders must be extracted by exposing it in a sufficient length of

pipe to the cooling influence of the atmosphere, or, still better, of water, or to that of both combined. If the whole of the heat imparted to the compressed air by the compression could be extracted by the water in the jackets of the air-compressing cylinders, there would, of course, be no necessity for any greater length of pipe than just enough to convey the compressed air to the air-expanding cylinder. The only purpose of the lengthened pipe exposed to the atmosphere and to water is to do what the water-jackets of the air-compressing cylinders failed to do for want of surface.

It is found that air taken from the atmosphere and compressed under constant temperature will not hold the same quantity of hygroscopic moisture which it held under only the atmospheric pressure, and the higher the pressure the greater will be the deposition of this moisture which must be removed before the compressed air is admitted to the air-expanding cylinder, for the double reason that the driest possible air is required, and that the ice which would be formed from this deposited water if admitted to the air-expanding cylinder, in which a very low temperature exists, would mechanically prevent the working of its valves and piston. The removal of this water of deposition is effected by a simple water-trap placed in the pipe just in advance of the valve-chest of the air-expanding cylinder, and so much of the hygroscopic water of the atmosphere is thus removed that no ice is found within the air-expanding cylinder whose mechanical action is not in the least impeded thereby. Of course, the pipe must be arranged to have a descent from the air-compressing to the air-expanding cylinder in order that the deposited water may flow to the trap by gravity. If the compressed air were cooled by the water in the jackets of the air-compressing cylinders to the atmospheric temperature, the deposition of the hygroscopic water would take place in them, and be forced out through a relief valve at the end of each compressing stroke of their pistons. But it might be found that more time is required for this deposition than is afforded in the cylinders, and that a certain length of pipe is needed for that purpose, irrespective of the extraction of any residual heat in the compressed air. This is a problem which can be solved by experience only.

From the pipe the compressed air, cooled to the atmospheric temperature and deprived of nearly all its hygrometric moisture, enters the air-expanding cylinder in which it undergoes refrigeration and develops power at the same time. This cylinder is furnished with induction, eduction, and cut-off valves, and a piston, precisely the same as the cylinder of a steam engine, and the air is used in it just as steam is used in a steam cylinder.

The piston of the air-expanding cylinder is connected by the usual piston-rod, crosshead, and connecting-rod with a crank on the same shaft that the steam piston is similarily connected with, so that this shaft is simultaneously operated by both the steam cylinder and the air-expanding cylinder, the work thus done, exclusive of what is absorbed by the frictions of the apparatus, *per se*, and of the load, being expended in the compression of the air within the air-compressing cylinders. The power, therefore, which compresses the air is the aggregate net power developed by the steam cylinder and by the air-expanding cylinder. Hence, the subtraction of the power exerted on the pistons of the air-compressing cylinders, as shown by the indicator diagram, from the sum of the indicated powers of the steam cylinder and air-expanding cylinder, leaves a remainder which is the power absorbed by the frictions of the entire machine, *per se*, and of the load. By the friction of the entire machine *per se* is meant the friction of all its moving parts due to their weight and to the tightness of the packings, from and inclusive of the piston of the steam cylinder to and inclusive of the connecting-rod of the air-expanding cylinder when the machine is unloaded, that is, when working at the experimental speed, but without compressing air. This friction is independent of and unaffected by the work of compressing the air, and the *pressure* on the pistons to overcome it is constant at all speeds of piston, the *power* being in the direct ratio of the piston speed. But, when the machine compresses air, there is brought into existence another

friction called the friction of the load, which is due to the additional pressure upon the moving parts caused by the additional resistance of the load. This latter friction has a fixed proportion to the load, and is independent of, and unaffected by, the former friction of the machine, *per se*. With the average lubrication of practice the friction of the load is 7½ per centum of the load.

The power shown by the indicator diagram for the portion 0.228 of the stroke of the piston of the air-expanding cylinder, comprised between the commencement of the stroke and the closing of the cut-off valve, though exerted *in* the air-expanding cylinder, was exerted *by* the pistons of the air-compressing cylinders, the communication being free from the latter to the former. After the closing of the cut-off valve the power exerted by the expansion of the air was exerted by the air-expanding cylinder, consequently, for overcoming the friction, *per se*, of that cylinder, there must only be subtracted from its indicated power what is required for moving the unloaded parts through the remaining $(1.000 - 0.228) = 0.772$ of the stroke of the piston, and for the friction of the load 7½ per centum of the remaining power exerted during the 0.772 of the stroke of the piston by the expanding steam above the back pressure against the piston. Hence, nearly all the frictions of the machine were overcome by the steam cylinder alone, the air-expanding cylinder contributing but little, as the expanding air in it exerted but little pressure above the back pressure in it.

The indicated horses-power expended in compressing the air was 40.7242. The aggregate indicated horses-power developed in the steam cylinder and in the expanding cylinder was $(38.4369 + 5.3868 =) 43.8237$; consequently, the horses-power expended in overcoming all the frictions of the machine were $(43.8237 - 40.7242 =) 3.0995$. Deducting from the aggregate indicated horses-power of 43.8237, developed by the machine, 1.0957 horses-power for overcoming the friction of the machine, *per se*, the remainder will be the horses-power applied to the crank-pins, namely, 42.728, of which 3.0995 horses-power is 7¼ per centum.

The pressure in the air-compressing cylinders from the opening of their delivery valves to the end of the stroke of their pistons was 142.100 pounds per square inch above zero, which fell to 140.515 pounds per square inch above zero as soon as the delivery valves were passed. The difference of the two pressures represents the force required to open the delivery valves and to deflect the current of the air from the direction of the piston course through several sinuosities into that of the pipe connecting the air-compressing cylinders with the air-expanding cylinder.

This pressure of 140.515 pounds, which was at one end of the pipe connecting the air-compressing cylinders with the air-expanding cylinder, fell, at the other end of the pipe, just before it entered the air-expanding cylinder, to 136.780 pounds per square inch above zero, the difference of 3.735 pounds per square inch representing the force required to overcome the surface resistance of the pipe to the air, and the resistance due to the numerous return bends in that pipe.

The adjustment of the admission valve to the air-expanding cylinder was so badly done that the maximum pressure was not attained in that cylinder until nearly the point of the stroke of its piston where the admission of the air was cut off. This unskillful adjustment of the valve, together with the too small area of the opening for admission, restricted the maximum pressure in the air-expanding cylinder to 93.000 pounds per square inch above zero, the loss of pressure between the valve-chest and the cylinder being 43.780 pounds per square inch, an excessive amount, most of which could have been avoided by proper mechanical arrangements and proportions, a difference of from 1½ to 2 pounds per square inch being easily obtainable. This great loss of pressure in the air-expanding cylinder materially lessened both the power recovered from that cylinder and the degree of refrigeration imparted to the air in it.

The point of cutting off in the air-expanding cylinder must be so regulated that the final pressure there will be just that of the back pressure against the

piston of that cylinder, care being taken by means of large openings and proper exhaust-valve adjustment, to make the back pressure as little above the atmospheric pressure as possible. Now, with a given quantity of air entering the air-expanding cylinder in a given time, and with the back pressure against the piston of that cylinder forming the lower limit of pressure, it is evident that the lower the initial pressure in the air-expanding cylinder the less will be the measure of expansion with which the air can be used; and the less the measure of expansion with which a given weight of air is used, the less will be the refrigeration of that air, for this refrigeration is in the direct ratio of the work done by the expanding air. Hence, the desirability of using the air in the air-expanding cylinder at the tension it received in the air-compressing cylinders less only the inevitable losses due to the transmission of that pressure from the pistons of the air-compressing cylinders to the piston of the air-expanding cylinder. Also, the higher the initial pressure and the greater the measure of expansion with which a given weight of air is used, the greater will be the power obtained from it. The function of the air-expanding cylinder is primarily to refrigerate the air used in it by the conversion into work of the heat of the air therein expanded calculated down to the atmospheric pressure; and, secondarily, to recover some of the power expended in air compression. The capacity of the air-expanding cylinder relatively to the capacity of the air-compressing cylinders should be so proportioned that the air being received by the former from the latter with as little loss of pressure as possible should be cut off at the earliest point which would make the final pressure after expansion just equal to the back pressure. These two pressures in the air-expanding cylinder, namely, the initial pressure upon, and the back pressure against, its piston, determine the measure of expansion with which the air can be used, as the expansion curve must pass through both.

There were discharged from the air-expanding cylinder at the end of the stroke of its piston only 368.806 pounds of air per hour, although the air-compressing cylinders had compressed 756.166 pounds of air per hour, the loss being 51.227 per centum of the weight received by the machine, leaving only 48.773 per centum of that weight delivered by it. This loss is due entirely to leakage of the highly compressed air out of the machine into the atmosphere and to its regurgitation past the pistons and valves.

Nothing is more difficult than making joints and packings sufficiently tight to hold highly compressed air, and the enormous velocity with which such air rushes into the atmosphere permits a great weight of it to escape through very insignificant openings. Practically, allowance must always be made for a loss of about one-half of the air compressed, and although this seems a large estimate, it will not be found too large for lengthened performance of the machine under the conditions of ordinary practice.

The number of Fahrenheit units of heat per hour taken out of the air discharged from the air-expanding cylinder was

$$(368.806 \times 117 \times 0.2382 =) \ 10278.4019,$$

which is equivalent to the work of expansion of 4.09708 horses-power. Now, the expanding steam alone in the air-expanding cylinder after the closing of the cut-off valve developed only 3.27304 horses-power, calculated down to the line of atmospheric pressure; consequently the complementary 0.82404 horses-power was supplied by the expansive working of the air discharged into the atmosphere at the end of the stroke of the piston. The pressure of the air at the end of the stroke of the piston was 16.092 pounds per square inch above the atmosphere, and, in its expansion down to the atmospheric pressure, must have done considerable work upon the atmosphere which it heated and itself underwent an equivalent refrigeration to the work thus done.

There were required to compress the air in the air-compressing cylinders 40.7242 horses-power, of which there were recovered for that work by the air-expanding cylinder 5.16008 horses-power; that is to say, of the 40.7242 horses-power expended in compressing air, only 5.16008 were contributed by the air-

expanding cylinder. The total horses-power, calculated down to the line of atmospheric pressure, developed in the air-expanding cylinder, was, indeed, 5.66549, the difference of 0.50541 horses-power being consumed in working the cylinder, *per se*, and in overcoming the back pressure against the piston above the atmospheric pressure.

Now, if the air had been compressed in the air-compressing cylinders at constant temperature and expanded in the air-expanding cylinder at the same, the latter would evidently have developed the same power as the former, supposing no loss of pressure between the cylinders and the expansion carried down to the atmospheric pressure. There has been shown that had the air been compressed at constant temperature, the horses-power developed in the air-compressing cylinders would have been only 24.7746, of which 51.227 per centum were lost by air leakage, reducing proportionally the 24.7746 horses-power to 12.08332, of which 5.66549 are accounted for by the air-expanding cylinder, leaving 6.41783 to cover the losses due to the want of expanding down to the atmospheric pressure; to the difference of pressure between that of the air in the air-compressing cylinders, namely, 142.100 pounds per square inch above zero, and that of the air in the air-expanding cylinder, namely, 93.000 pounds per square inch above zero at the beginning of the stroke of the piston, and 87.000 pounds at the closing of the cut-off valve, as well as the loss of pressure due to the refrigeration of the expanding air in the air-expanding cylinder, and the loss of air effect in the clearance and passage at the end of the air-expanding cylinder; likewise, the loss of the mechanical effect due to the weight of aqueous vapor condensed in the connecting pipe and trapped out.

The weight of air delivered per hour by the air-expanding cylinder being 368.806 pounds, and the refrigeration effected upon it being a fall in temperature of $(-57^\circ + 60^\circ =)$ 117 degrees Fahrenheit, the number of Fahrenheit units of heat destroyed per hour by the machine is $(368.806 \times 117 \times 0.2382 =)$ 10278.4019. That is to say, the quantity of heat destroyed per hour was sufficient to raise the temperature of 10278.4019 pounds of water at 32 degrees Fahrenheit one degree, or, as the latent heat of ice is 142.5 degrees Fahrenheit, the destruction of the above quantity of heat was sufficient to produce per hour from water at the temperature of 60 degrees Fahrenheit $\left(\frac{10278.4019}{60^\circ - 32^\circ + 142.5} =\right)$ 60.2839 pounds of ice at the temperature of 32 degrees Fahrenheit.

The quantity of air cooled per hour one degree Fahrenheit was $(368.806 \times 117 =)$ 43150.302 pounds, and as a pound of air at the temperature of 60 degrees Fahrenheit and under the standard atmospheric pressure occupies 13.44945 cubic feet, the refrigeration was equal to cooling per hour under that pressure $(368.806 \times 13.44945 =)$ 4960.2379 cubic feet of air one degree Fahrenheit, or $\left(\frac{4960.2379}{60^\circ - 32^\circ} =\right)$ 177.1513 cubic feet of air from the temperature of 60 degrees Fahrenheit to that of 32 degrees.

To accomplish this refrigeration there were expended in the actual condition of the machine 40.7242 net horses-power; that is to say, power exclusive of all frictions, whether of the machine, *per se*, or of the load. This is the power exerted on the pistons of the two air-compressing cylinders, as measured by the indicator, and for the mean pressure above the atmosphere. A net horse-power was therefore equal, under the actual conditions of the machine, to the lowering per hour of the temperature of $\left(\frac{10278.4019}{40.7242} =\right)$ 252.3905 pounds of water at 33 degrees Fahrenheit to 32 degrees; or, to the production per hour of $\left(\frac{60.2839}{40.7242} =\right)$ 1.4803 pounds of ice from water at the temperature of 60 degrees Fahrenheit; or, to the cooling per hour of $\left(\frac{43150.302}{40.7242} =\right)$ 1059.5740 pounds of air one degree Fahrenheit; or, to the cooling per hour of $\left(\frac{177.1513}{40.7242} =\right)$ 4.3500

cubic feet of air from the temperature of 60 degrees Fahrenheit to that of 32 degrees.

With a properly conditioned machine, the foregoing quantities of refrigeration could have been produced for about one-half of the above 40.7242 horses-power, and still allowed an air leakage of about one-half of the air compressed; indeed, had the heat of compression been taken out of the compressed air as fast as generated, the leakage would have been lessened, as the mobility of air is greater with greater temperatures.

The engineering skill with which the machine was designed was exceedingly faulty, and the fuel cost of the work done was proportionally and unnecessarily great. To operate the machine with the utmost economic advantage, the steam should be used in the steam cylinder according to the known methods producing the horse-power with the least expenditure of fuel, instead of which the steam was used in the most wasteful manner possible. It was not superheated; it was used absolutely without expansion; the cylinder was not steam-jacketed; the steam was admitted to the cylinder at the low initial pressure of 45 pounds per square inch above the atmosphere for a non-condensing engine, although the boiler pressure was 60 pounds per square inch above the atmosphere; the mean back pressure against the piston during its stroke was, owing to the very defective setting of the steam valve, 25.77 pounds per square inch above zero, the mean total pressure on the piston being only 54.682 pounds per square inch above zero, whereby nearly one-half of the steam was uselessly employed in overcoming the back pressure alone. Under these conditions the indicated horse-power cost 7.7291 pounds of anthracite per hour, which is about three times its cost with the most economical steam engine and the same economic vaporization by the boiler.

The air-expanding cylinder used the compressed air as extravagantly as the steam cylinder used the steam. Now, in order to obtain the most economical results from the expansion of the air, it should enter the expanding cylinder at the maximum pressure in the air-compressing cylinders, less only the inevitable loss of pressure due to its transfer, and the cut-off valve should close as soon as a sufficient quantity was admitted to produce a pressure at the end of the stroke of the piston equal to the back pressure against the piston, which by means of large exhaust openings, should be reduced to that of the atmosphere, the cylinder being made of the proper capacity, relatively to the weight of air supplied per stroke of piston by the air-compressing cylinders, to allow such a distribution. Of course the valves and piston should be as tight as practicable, and the air-expanding cylinder should be well covered with non-heat-conducting substances. The setting of the admission valve of this cylinder was so injudicious that the maximum pressure was not attained in it until after the piston had commenced its stroke, and when attained was far below what should have been. The air refrigeration is produced wholly by the expansion of the air when doing work. All the air that escapes use expansively upon the piston in doing work escapes refrigeration. The air should be expanded in doing this work as much as possible without falling below the atmospheric pressure, because if it did the power developed byit would be decreased and an economic loss sustained in that particular, and it should fall to that pressure in order to secure the greatest practicable expansion and consequent greatest practicable refrigeration. To obtain the greatest practicable degree of expansion it is evident that the initial pressure of the air must be the highest practicable, and its final pressure the lowest practicable. Now, the air pressure in the pipe connecting the air-compressing and the air-expanding cylinders was, just before entering the latter, 122.000 pounds per square inch above the atmosphere, while the maximum pressure in the air-expanding cylinder was only 78.222 pounds per square inch above the atmosphere. The pressure of the air in the air-expanding cylinder, at the end of the stroke of its piston, was 16.072 pounds per square inch above the atmosphere. These figures show how much less than the possible were the actual results, and they do not include the enormous unnecessary loss caused by not removing the heat of compression as fast as generated.

PRINCIPLES OF THE MACHINE.

If a given mass of air be taken at a given pressure, compressed to another, and then expanded back to the original pressure, its temperature remaining constant during these operations, the power developed or work done by its expansion will exactly equal the power exerted or work done in its compression, supposing the mechanism by means of which these operations are produced to have neither friction nor to leak air.

If there be friction and air leakage, the power developed by the expansion will be less than that exerted in the compression by the amount of the friction and leakage.

But if the air be kept at constant temperature during its compression only, receiving no heat during its expansion, then, during the expansion, its temperature will be lowered by the annihilation of so much of the heat contained in it as is equivalent to the power developed during the expansion, the air becoming more and more refrigerated as it is more and more expanded, and its pressure becoming less and less in the compound ratio of its expansion and refrigeration, so that the power developed during the expansion will be less than that exerted during the compression by the amount of the lessening of the pressure due to the refrigeration.

As the air on which the operations of compression and expansion are performed is taken from the atmosphere, the atmospheric pressure is their lower limit of pressure, and the final pressure of expansion should always equal it. There is, however, no upper limit of pressure, the compression being conceivable to any degree, and the higher this upper limit the greater will be the expansion.

The greater the expansion of a given mass of air expanded without receiving heat, the greater will be its refrigeration, because the more it is expanded the more power it will develop, and the refrigeration is directly proportional to this power. But the degree of expansion possible for the air can only equal the degree of compression it received, or, in other words, the compression and the expansion can be only between the same pressures, and will have an invariable relation. And as the refrigeration is proportional to the expansion, and as the expansion is proportional to the compression, the refrigeration will be proportional to the compression also. Hence, as the power producing the compression is the cost of the refrigeration, there is no economic gain in the production of a given quantity of refrigeration represented by mass of air multiplied by fall of temperature by giving the air a greater degree of compression in order that it may have a corresponding greater degree of expansion. All degrees of expansion and compression have the same economic value; that is to say, the expenditure of the same power in compressing a given mass of air, let the degree of compression be what it may, produces the same quantity of refrigeration by its corresponding expansion.

If, however, the object be merely to produce the minimum temperature in the expanded mass of air, then its compression at constant temperature should be carried to the highest practical limit in order that its expansion may be proportionally great and its resulting temperature correspondingly low. Nevertheless, nothing is economically gained or lost as regards quantity of refrigeration so produced, the power cost being always proportional to this quantity and unaffected by the final temperature. The minimum temperature of compression is, of course, the atmospheric temperature.

The power developed by the expanding air is, of course, applicable to the compression of air in conjunction with power derived from other sources.

The entire refrigerating effect is produced by the conversion of heat into work during the expansion of the air overcoming a resistance; and for the refrigeration to be a maximum, this resistance must never be less than the pressure of the expanding air. Heat and work being mutually convertible in the fixed relation of 789¼ foot-pounds of work as the mechanical equivalent of one Fahrenheit unit of heat, the fall of temperature in one pound of air doing

work by its expansion is one degree Fahrenheit for every (789¼ × 0.2382 =) 187.99935 foot-pounds of work so done.

When the air expands without overcoming any *external* resistance its refrigeration is very slight, being due to only the *internal* work done upon it by its contained heat in overcoming its own cohesion. The experiments of Joule and Thomson on this subject showed that when air expanded without doing external work its temperature fell five degrees Fahrenheit for the difference of twenty-one atmospheres between its initial and final pressures; and that this fall of temperature was directly proportional to the fall of pressure, which would give for each difference of pressure of one pound per square inch, a fall of temperature of 0.01621 degree Fahrenheit.

If the air be not compressed at constant temperature, but have, during its compression, an increasing temperature caused by the work of compression done upon it, and if this additional temperature so obtained be abstracted by external cooling appliances after the compression has ended and before the expansion has begun, then the whole of the work expended in overcoming the pressure due to the heat of compression is lost, for the quantity of air compressed is the same whether the compression be done at constant temperature or increasing temperature, and the power or work recovered from the expansion is the same, because the same quantity of air at the same temperature will be expanded the same degree or number of times in both cases. The power developed by the expansion has a fixed relation to the power exerted in compression only when the compression is done at constant temperature.

If the expansion, instead of being carried down to the atmospheric pressure, is terminated before that pressure is reached, and the air be then discharged with excess of pressure into the atmosphere, whose resistance is consequently less than that of the expanding air, the latter will expand to the atmospheric pressure, and in so expanding will do work, though less in quantity than if expanding against a resistance equal to its pressure, and will undergo a refrigeration proportional to the work done in expanding against the atmospheric pressure. Of course, the atmosphere upon which the work of this expansion is done undergoes a heating equivalent to the refrigeration experienced by the expanding air.

If the compressed air, after having its temperature reduced to that of the atmosphere, be made by mechanical apparatus to commence its expansion at a lessened pressure, in which case the same quantity of air will be expanded down to the same atmospheric pressure, but the work done by its expansion will be less than if the expansion had been commenced at the maximum pressure, and the refrigeration will consequently be less; and, further, the power recovered from the air thus expanded will be less.

To give practical effect to the foregoing principles, a machine has to be constructed consisting of a steam cylinder, if a steam engine be the motor employed for compressing the air, an air-compressing cylinder for the compression of the air, and an air-expanding cylinder for the expansion of the air, as the compression and expansion of the air are not practically manageable in the same cylinder. These two cylinders must be in communication with each other by means of a pipe for the transfer of the air from the former to the latter. The steam cylinder and the air-expanding cylinder are articulated to the same shaft, and this shaft works the piston of the air-compressing cylinder, so that whatever power is developed by the expanding air is recovered for air compression. The air-compressing cylinder must be single-acting, but the air-expanding cylinder can be double-acting and must be fitted with a cut-off valve.

The machine being arranged to work at a given maximum pressure, which is effected by making the cut-off valve of the air-expanding cylinder to close earlier or later in the stroke of its piston, and set in motion, the air-compressing cylinder receives during the indraught stroke of its piston its capacity of air of atmospheric pressure, which it compresses on the return stroke to the

maximum pressure; and this compression may be done at constant temperature if the heat of compression be extracted as rapidly as generated, or at increasing temperature if that heat be not so extracted. These form two cases in making computations of the results obtained, beside which there are mechanical causes inseparable from the use of mechanism which influence these results, and sometimes to a marked degree. In this machine, as well as in all others, there are differences between theoretical prediction and practical performance, but they can be ascertained and allowed for.

First. When the compression is accomplished at constant temperature in the air-compressing cylinder. In this case the tension gradually increases, according to the Mariotte law, from the commencement of the stroke of the piston until the maximum tension is reached, which will always be before the piston arrives at the end of its stroke, the curve of compression being a hyperbola. At the point of maximum tension, the air-delivery valve opens, and the tension remains constant to the end of the stroke of the piston. The work of compression is measured by the mean pressure of the air above the atmospheric pressure from the commencement of the stroke of the piston of the air-compressing cylinder to the point in that stroke where the maximum tension is reached, multiplied by the distance from the commencement of the stroke to the point of maximum pressure, for after this pressure is attained there is no more air compression. The work done by the piston for the remaining portion of its stroke, measured by the product of that portion into the maximum pressure above the atmospheric pressure, is transferred to the piston of the air-expanding cylinder by means of the air in the connecting pipe between these two cylinders, this intervening air acting as a solid block would act in communicating the pressure from the piston of one cylinder to the piston of the other. Thus, the work done in the air-compressing cylinder after the compression has ceased is directly recovered in the air-expanding cylinder, with the exception of the inevitable loss of pressure due to transferring the air from the one cylinder to the other, caused by the deflections of the air current at the valves of the cylinders and at the bends of the pipe, by the resistance of the interior surfaces of the pipe to air movement, and by the throttling of pressure due to insufficient valve opening. The degradation of pressure due to these causes will be greater the faster the machine works, and should be restricted as much as practicable by giving large openings to the valves, large diameter to the pipe, and few bends. Of course, barring leakage, the same weight of air at the same temperature enters the air-expanding cylinder as leaves the air-compressing cylinder, but the pressure at which it enters the former will be less than that at which it leaves the latter, so that a loss of effect is experienced, measured by the difference of these two pressures.

There is also another loss of effect in the air-expanding cylinder due to the spaces in the clearances and air passages at the ends of the cylinder, in consequence of which the mean pressure on the piston of that cylinder during both the non-expansive and the expansive portions of its stroke will be less than if there were no such spaces, so that the work or power recovered in the air-expanding cylinder will be proportionally less than it would be did these spaces not exist. And, further, the air in consequence of this less work done by its expansion will be less refrigerated. All losses of work in the air-expanding cylinder are not only losses of power which ought to be recovered there, but involve losses of refrigeration for the air, so that the disadvantage is twofold.

Another loss of power may exist, although not necessarily, in the air-expanding cylinder, due to the insufficient opening of its exhaust valve, which causes the back pressure against its piston to exceed the atmospheric pressure. This excess is a total loss of power that ought to have been recovered, but it does not affect the refrigeration, because overcoming it is as much work done by the expanding air as if the power was expended on the crank-pin. This defect only requires a large exhaust valve opening for its removal.

The expanding air in the air-expanding cylinder may receive heat from the atmosphere or from other surrounding bodies, and to that extent its pressure will be increased and also the power it develops proportionally. This is a gain for the power recovered, but a loss for the refrigeration, and should be avoided by clothing the air-expanding cylinder with non-heat-conducting substances.

The power developed in the air-expanding cylinder during the portion of the stroke of its piston previous to the closing of its cut-off valve is the exact reproduction of the power developed in the air-compressing cylinder after the opening of its delivery valve, less the losses just described, and is, therefore, so much power recovered. A further recovery of power then takes place by the expansion of the air through the remaining portion of the stroke of the piston of the air-expanding cylinder, and that this recovery may be as large as possible, the expansion must be continued down to the back pressure against the piston. The power thus recovered is measured by the product of the mean pressure of the expanding air above the back pressure into the portion of the stroke of the piston during which the expansion is operative, and corresponds to the power expended in compressing the air in the air-compressing cylinder, less the losses due to lessened pressure before expansion commences, to the waste spaces in the air-expanding cylinder, to the excess of the back pressure over the atmospheric pressure, to not expanding the air down to the back pressure, and to the refrigeration of the air itself due to the work of its expansion, the latter only of which is considered in a purely theoretical investigation of the subject, as it results inherently from the working of the machine. The entire refrigeration of the air up to the instant when the exhaust-valve opens at the end of the stroke of the piston of the air-expanding cylinder is due to the power developed by the expanding air from the point in the stroke at which the cut-off valve closes to the end of the stroke, calculated down to the back pressure against the piston; if the expansion in the cylinder has been carried down to the atmospheric pressure, no more refrigeration can be obtained; but if, on the contrary, the pressure of the expanding air at the end of stroke of the piston is greater than the atmospheric pressure, there will be a further refrigeration of the air when the exhaust-valve opens, due to the work of expansion that the air will perform in expelling itself from the cylinder into the atmosphere. But as the atmospheric pressure is less than that of the air discharged into it, the latter will not develop as much power as though the expansion had been continued in the cylinder down to the atmospheric pressure, and, consequently, the total or final refrigeration of the air will be less than in that case; nevertheless, the additional refrigeration gained by the discharge of greater pressure into the atmosphere will be considerable and in proportion to the excess of pressure. Both power recovered, however, and refrigeration will be increased by carrying the air expansion down to the atmospheric pressure.

From the power above the back pressure against the piston, recovered in the air-expanding cylinder, there must be subtracted the power required to work that cylinder and its appendages, *per se;* that is to say, to overcome the friction due to the weight of its moving parts and to the tightness of its packings; the remainder is only what is recovered on the crank-pin. This friction power is chargeable to only the portion of the stroke of the piston from the closing of the cut-off valve to the end of the stroke, as previous to that closing the power required to overcome the friction in question was supplied by the air-compressing cylinder.

The power compressing the air in the air-compressing cylinder is equal to the sum of the powers exerted in the steam cylinder and in the air-expanding cylinder, less the power required to overcome the frictions of the machine. Consequently, if indicator diagrams be taken simultaneously from the steam cylinder, the air-expanding cylinder, and the air-compressing cylinder, the difference between the sum of the indicated powers developed in the former two and the indicated power shown in the latter will be the power required to overcome all the frictions of the machine.

These frictions are of two kinds. One is that of the machine *per se*, or what is due to the weight of the *unloaded* moving parts and to the tightness of the packings (the air resistance to the moving parts being too inconsiderable to be included in a practical investigation); the power to overcome this friction is directly as the speed, the piston pressure being constant for all speeds. The other friction is what is due to the net power, or power applied to the crank-pins, and the power required to overcome it is proportional to the power applied to them. The articulations of the machine when at work are pressed by the pressure producing the net power, which consequently excites friction at those points in the direct proportion to that pressure. These two kinds of friction are entirely independent of each other, and must be dealt with separately in computation.

Finally, there is a loss of theoretically recoverable power due to the precipitation of a large portion of the moisture in the atmospheric air compressed. This air, after compression at constant temperature, cannot hold as much aqueous vapor as before compression, and the vapor is consequently continuously deposited in the form of water as the tension of the air continuously increases, involving a loss of mechanical effect measured by the bulk of vapor thus condensed.

Under purely theoretical conditions the power recovered in the air-expanding cylinder would exactly equal the power expended in the air-compressing cylinder less the power due to the loss of pressure in the expanding air caused by its refrigeration while doing work.

All the foregoing deductions are for the case of constant temperature for the air during its compression, but the temperature may not be constant which forms case —

Second, in which the compression is accompanied by a continuously increasing temperature, the heat equivalent to the work of compression not being abstracted from the air as fast as generated.

In this case the heat has to be taken out of the compressed air after the latter has received its maximum tension and before its expansion has commenced, the abstraction of the heat being performed in the pipe connecting the air-compressing and the air-expanding cylinders. This pipe receives the air from the former cylinder at maximum temperature, and delivers it at the atmospheric temperature to the latter cylinder.

The maximum tension is obtained in the air-compressing cylinder, and is acquired before the piston of that cylinder reaches the end of its stroke; yet, notwithstanding this, the compression goes on during the remainder of the stroke, but without increase of pressure, because when the maximum pressure is obtained, the delivery valve opens, putting the interiors of the air-compressing cylinder and of the pipe in common; and as in the latter the air is undergoing continuous shrinkage of bulk owing to continuous decrease of temperature, the piston of the air-compressing cylinder maintains the constant maximum pressure by continuously squeezing up the air of falling pressure due to the falling temperature; consequently the whole of the power developed in the air-compressing cylinder—that is, the power measured by the product of the mean pressure in the cylinder above the atmospheric pressure, into the entire stroke of its piston—is employed, not only in forcing the piston of the air-expanding cylinder from the commencement of its stroke to the point where the cut-off valve closes, but in compressing air, and it is the heat of this compression which is generated in the air-compressing cylinder and has to be extracted.

The above considerations are not modified by the fact that part of the heat of compression may be taken out of the air before it leaves the air-compressing cylinder, as the pressure on the indicator diagram would thereby be proportionally reduced.

Now, as the power developed in the air-expanding cylinder is from a given weight of air of the atmospheric temperature at a given pressure, irrespective of what may be the temperature of this weight of air at the given pressure

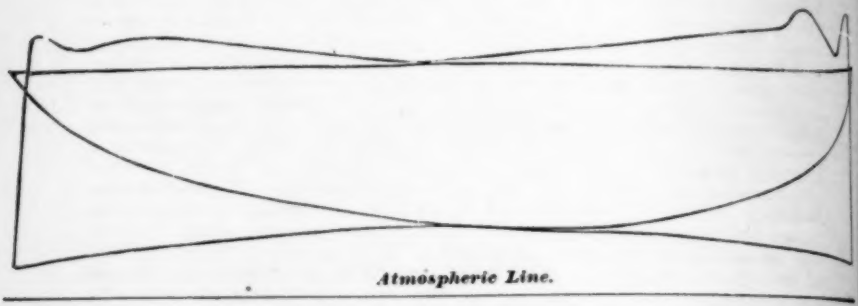
when it leaves the air-compressing cylinder, it is evident that the power recovered by the expanding air is, under the circumstances, a fixed quantity, let the power expended on the compression be what it may; so that whatever excess of power is developed in the air-compressing cylinder due to the greater bulk there of the given weight of air to be compressed to the given pressure, which greater bulk is caused by the greater temperature, is entirely lost. That is to say, the difference of power between what is required to compress a given weight of air at constant temperature to a given pressure in the air-compressing cylinder, and what is required to there compress the same weight of air at increasing temperature to the same pressure, is entirely lost.

The losses of mechanical effect in the air-expanding cylinder, either in kind or quantity, are entirely uninfluenced by the more or less heat of compression in the air-compressing cylinder, and remain as previously described.

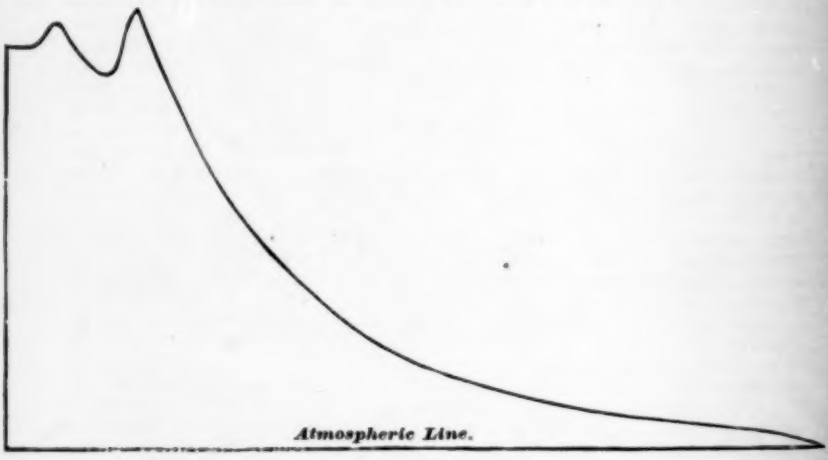
A comparison of the bulk and weight of the experimental machine, with the quantity of refrigeration it produces, even if by more skilful adjustment that quantity were doubled, shows how inefficient is the system of cooling by air expansion when the cost and quantity of the mechanism to furnish it are considered. This inefficiency is due to the fact that, owing to the low specific gravity and high specific heat of air,—a mixture of fixed gases—an enormous machine is needed for the production of but a small quantity of refrigeration; consequently, when large quantities of cold air are required for ventilation on board ship, and for respiration by the numerous personnel embarked, the weight and bulk of an adequate machine make its employment out of the question. For a hospital its use is practicable for cooling an apartment in which air dry and much refrigerated is required for the successful treatment of certain diseases and for surgical operations in hot weather. Its use is also practicable for the refrigeration of large apartments, indeed, the entire holds on board ship, in which fresh meats and fresh vegetables are to be transported, as in that case there is required only cooled air enough to compensate the increase of temperature by radiation from the walls of the apartment and by inleakage of external air through them, which, by proper non-heat-conducting covering and by being made air-tight, can be reduced to an insignificant amount.

The great practical advantage of the air-refrigerating machine is its simplicity, and the fact that air, the substance operated with, is found everywhere without cost and is innoxious. But, if air be all-present and abundant, water is not, and that is required in considerable quantities for absorbing the heat of compression. This heat can indeed be taken up by the external atmospheric air, but the operation is excessively slow and requires an enormous extent of pipe surface between the air-compressing and the air-expanding cylinders, besides involving a maximum loss of power in performing the compression. The temperature, too, of the air-compressing cylinder would be inconveniently great, in fact, impracticably great, if the compression were carried to any high degree.

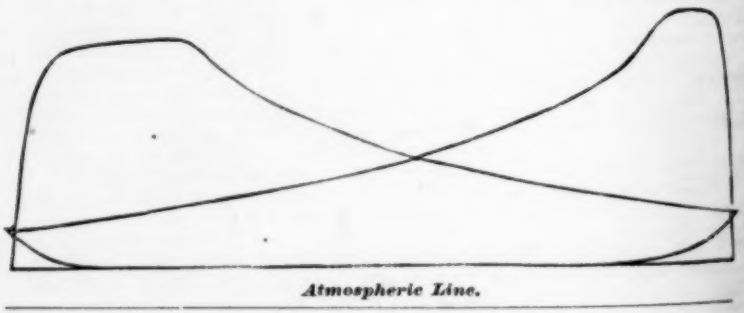
INDICATOR DIAGRAMS FROM THE THREE CYLINDERS SHOWING THE DISTRIBUTION OF THE PRESSURES.



Indicator diagram from steam cylinder. Scale 36 *pounds per square inch per inch.*



Indicator diagram from air-compressing cylinder. Scale 59 *pounds per square inch per inch.*



Indicator diagram from air-expanding cylinder. Scale 59 *pounds per square inch per inch.*

THE EDISON ELECTRIC LIGHT ON BOARD THE U. S. FISH COMMISSION STEAMER ALBATROSS.

EXTRACTS FROM A REPORT MADE BY LIEUT. SEATON SCHROEDER, U. S. N.

There are 136 Edison incandescent lamps in place on board this vessel; of that number, under ordinary circumstances 40 to 45 are generally in operation the greater part of every evening, beginning at dark and ending at about 11 P. M.

During the quarter ending March 31, 1883, eighteen lamps have been disabled, as follows:

10 Broken in handling.
4 Burned out.
1 Burned out by short circuiting of two branch wires.
1 Gradually unscrewed from socket, owing to vibration of hull, and fell on deck, breaking the glass and filament.
1 Carbon filament broken by caulking the deck above.
1 Carbon filament broken while experimenting.

The invoice price of each lamp being one dollar, the additional cost of illumination on account of breakage of lamps has been $18.00, over and above first cost of plant.

During the quarter the dynamo-machine has run 540 hours. Of the 136 lamps in position 34 have been in operation the whole time, or 540 hours each = 18,360 hours in all; of the remainder, the hours of incandescence have been as follows:

2	— 440	hours	each =	880	hours.
4	— 410	"	" =	1,640	"
22	— 340	"	" =	7,480	"
8	— 100	"	" =	800	"
20	— 50	"	" =	1,000	"
18	— 10	"	" =	180	"
			=	11,980	"
34	— 540	"	" =	18,360	"
	Total, . . .		=	30,340	"

The running expense in lamps has therefore been $\frac{\$18}{30340} = 59$ one-thousandths of a cent per lamp in operation per hour. For illuminating the entire vessel the running expense in lamps has been $\frac{\$18}{540} = 3\frac{1}{3}$ cents per hour.

The life of the lamps that have burned out has been as follows:

No. 49 (8-candle power)	. . . . .	92 hours.
" 90 (8-candle ")	. . . . .	369 "
" 68 (16-candle ")	. . . . .	195 "
" 41 (8-candle ")	. . . . .	99 "

A mean of these would obviously be a very unfair showing of the average life of the Edison lamp. The imperfect ones give way first, and a correct

average, of course, can only be had by waiting to consider the best as well as the poorest. It is only fair also to add that the breakage by accident has been greater than will probably continue to be the case, the crew being extremely raw, green, and unthinking. In handling the lamps (frequently without authority) they have apparently used more force, as a rule, and less dexterity than the occasion required, simple as their manipulation is. Familiarity with the light will doubtless decrease this source of expense.

Furthermore, the lamp that was disabled by caulking overhead was purposely left in place to test its safety under those conditions, it being attached to the deck that was being caulked; the burning of one by short circuiting occurred before the installation of the system was completed, and resulted from the loose ends of two branch wires coming in contact; the destruction of a third occurred during, and was apparently caused by, some experiments, which proved an abnormal condition for an incandescent system of illumination.

As shown above, only four of the eighteen have burned out, which would reduce the legitimate running expense to $\frac{\$4}{30340} = 13$ one-thousandths of a cent per lamp in operation per hour, or $\frac{\$4}{570} = 74$ one-hundredths of a cent per hour, for lighting the vessel.

Some of the globes have begun to be discolored by the wasting of the filaments (Crooke's effect), but not sufficiently to affect sensibly the amount of light given out.

Apart from questions of economy, the light commends itself strongly for use on shipboard. Its chief advantages over the means of illumination in common use afloat, are:

1. The absence of heat, smoke, smell, and dirt, and the non-consumption of oxygen; important points at all times, and especially in bad weather, when hatches are closed.

2. The almost absolute immunity from danger of fire; even in cases of short circuiting or arcing between two branch wires, which are the only ones liable to this mishap, the destruction of the safety-plug is simultaneous with the passage of the small spark, the circuit being thus instantly broken, and further danger avoided.

3. The great convenience of having it ready to turn on in any place, including the magazine passage, holds or store rooms, where otherwise an oil lamp would have to be used with its peculiar characteristics of dimness, dirt, and danger.

4. Its ability to remain in operation under water, when it may frequently be useful in examining or repairing a ship's bottom, or clearing a hawser from the propeller at night. It is likewise unaffected by rain or wind.

The steadiness of the light and its softness combine to make it most agreeable to the eye, and excellent for reading or working on a chart. The brilliance, of course, depends upon the velocity of the dynamo-machine, and the amount of resistance introduced into the circuit of the field magnets; but with average incandescence it is found that ordinary print can be read with comfort on a table by the light of one 16-candle, or two 8-candle lamps, four feet above it, fitted with porcelain shades. With one 8-candle lamp in that position, the print cannot be easily read without a tin reflector, which materially affects the dispersion of the light about the room. Four 8-candle lamps, with shades, situated four feet above a mess table seating twelve persons, illuminate it brilliantly.

The berth-deck of the vessel is 42 feet long, 23 feet average breadth, and 8 feet high. It is lighted by six 8-candle lamps, three on each side. They illuminate it thoroughly, so that the numbers on the bags or hammocks can be read with perfect facility in any part or in any position.

The fore-hold has, on the after bulk-head, one 8-candle lamp on each side, with tin reflectors. By the light of one of them, any piece of gear or object of any kind on the same side of the hold can be immediately recognized

throughout its length (25 feet), and could easily be picked out at a greater distance.

Throughout the entire vessel, the efficiency of the illumination is the same, and is a great source of convenience and comfort to all serving on board.

The great convenience of the portable hand and stand lamps need not be dwelt upon, as that is the same on shipboard as on shore. One of 16-candle power has been tried as a submarine light, its flexible cord and socket being wrapped with insulating tape. It has been under water, in all, sixty hours so far, with perfect impunity. At sea, with clear water, its light has been traced until it reached a depth of 100 feet; and after being in operation all one night at a depth of 150 feet (the length of the cord), it was found to be still air- and water-tight when hauled up, and is apparently in as good condition now as those in ordinary use.

Extracts from a Report made by Passed Assistant Engineer George W. Baird, U. S. N.

The economy of the Edison incandescent system of lighting is a question of commercial as well as engineering importance, and as this is the first Government vessel to utilize this important invention, I have considered it necessary to make more than the usual test of the machinery, that we may obtain figures which will enable the Commissioner to judge intelligently as to its real and comparative value.

First, the *Plant* consists of an engine of the Armington and Sims make, having a single cylinder of 8½ inches diameter of bore and a stroke of piston of 10 inches. The engine is horizontal, is mounted on a rigid cast-iron bed-plate, and has a centrifugal governor in the fly-wheel; the governor weights are connected to internal and external eccentrics and operate by shifting these eccentrics in equally angular and opposite directions, which diminishes the throw of the valve (without effecting the lead), and thus effects a shorter cut-off. It is sensitive, and, so far as I can measure, regulates the speed of the engine to 300 revolutions a minute without regard to the initial pressure on the piston or the resistance on the dynamo.

Second, a Z dynamo, having its field magnets vertical, the armature revolving in the field between the magnets, in the induced current. A resistance box is placed in the circuit of the magnetic field which regulates the pressure, and, by altering the switch on the resistance box, the incandescence of the lamps is raised or lowered at pleasure. The object of this method is to equalize the internal and external resistance, that the maximum economic effect may be realized, hence the great economy of the Edison system. For example, the dynamo is designed for 120 B lamps of 8-candle power each, and if only 60 lamps be in circuit the resistance of the circuit will be doubled and the field resistance must be switched in to balance it.

Third, there are 139 eight candle-power B lamps of 69 ohms resistance each, placed in multiple arc, and so distributed through the vessel as to illuminate every place where light is required. There are four circuits (of copper wire) from the dynamo, viz. a double circuit—main—on each side of the ship, for the forward lamps; a double circuit, on each side of the ship, for the after lamps; a single independent circuit for the outside lamps with the switch in the engine room, and an independent circuit for the engine room. The mains are not only double circuits, but each main consists of two No. 10 wires. The advantage of this system of wiring is manifest; in the event of breaking a wire, from collision or other cause, the remaining wires would be ample to carry the current. The mains, however, are brought together and soldered where they are attached to the binding posts of the dynamo. The wires are insulated with cotton cloth and white lead, and when passing through damp places they are further protected by rubber tubing. On each main wire, and near the dynamo (as well as near each group of lamps), is a "cut-out plug" or "safety catch,"

which contains a short piece of fusible alloy. The office of this plug is two-fold; it may be used as a switch to cut that wire out of the circuit at pleasure, and also to prevent the heating of the wires beyond the fusing point of the alloy (400 degrees), thus rendering the system harmless as a fire agent. These "cut-outs" are essential, as the copper wires would, in event of a short circuit, melt and set fire to adjacent woodwork.

The absolute safety of the Edison system, against injury to human life, commends it very highly. The low pressure of 51 volts is insufficient to pass through a man's body, and can, therefore, never injure him.

MANNER OF MAKING THE EXPERIMENTS.

By means of a steam engine indicator I measured the power required to run the engine and dynamo, the current being switched off. By the same instrument I measured the indicated power required to run 45, 50, and 70 lamps, respectively. . . . By deducting from these experiments, respectively, the power required to run the engine and dynamo, we obtain the power applied to the shaft, and from this quantity we deducted the friction of the load, leaving, as a remainder, the net powers required to revolve the armature, in the magnetic field, with 45, 50, and 70 lamps in circuit.

DISTRIBUTION OF THE POWER.

Power required to run the engine and dynamo	3.56
Indicated horse-power required to run 45 incandescent lamps	5.79
Indicated horse-power required to run 50 incandescent lamps	5.85
Indicated horse-power required to run 70 incandescent lamps	6.92
Net horse-power applied to the revolution of the armature in the magnetic field, using 45 incandescent lamps	1.80
Net horse-power applied to the revolution of the armature in the magnetic field, using 50 incandescent lamps	1.85
Net horse-power applied to the revolution of the armature in the magnetic field, using 70 incandescent lamps	2.84
Mean number of incandescent lamps per indicated H. P. using 45 lamps	7.77
Mean number of incandescent lamps per indicated H. P. using 50 lamps	8.50
Mean number of incandescent lamps per indicated H. P. using 70 lamps	10.11
Mean number of incandescent lamps per net H. P. using 45 lamps	25.
Mean number of incandescent lamps per net H. P. using 50 lamps	27.02
Mean number of incandescent lamps per net H. P. using 70 lamps	24.63

The wires being fixed, their resistance may be considered a constant quantity and the only variation as existing in the engine and dynamo; the distribution of the power as above recorded may, if necessary, be verified by electrical measurements on the wires.

RELATIVE ECONOMY OF THE LAMPS.

The cost of running the incandescent lamps, as compared with coal-gas lighting, is a matter of commercial as well as engineering interest, and it is my purpose to confine the comparison to these objects alone. From the quantities determined and recorded above, these comparisons are made, candle-power for candle-power.

So far the greatest number of lamps in operation at one time has been 70; we ordinarily use from 45 to 50. The number of lamps per indicated horse-power increases with the number of lamps used, for the reason that the engine works more economically at higher powers.

The comparison between these incandescent lamps and light from coal gas, as measured by a photometer, is not a fair one, inasmuch as the gas-burner itself (to say nothing of part of the fixture) is under the jet and casts a shadow underneath, while the Edison lamps are inverted and the shadow is above. As

the light is used under the lamp, a larger percentage of light from the inverted fixture will be cast upon the work beneath, and for this the photometer makes no reduction.

Although the B circuit is installed to give 8-candle power lamps they really emit about 10, which is also an unbalanced account in favor of the electric lamps.

The cost, in coal, of a horse-power developed by the dynamo engine has been arrived at by calculating the quantity of steam passed through the steam cylinder, and reducing this to pounds of water and dividing this by the pounds of water evaporated by a pound of coal. Had steam been used for lighting alone, this calculation would have been unnecessary, but as steam was used, from the same boiler, to warm, ventilate, and light the ship at the same time, the writer adopted this method of separating the respective powers. From these indicator diagrams I have calculated that a horse-power costs 30.7 pounds of water or 3.41 pounds of coal per hour. The cost of the coal was $4.60 per ton, and the lubricating oil 65 cents per gallon. The consumption of oil is one quart in six hours, so that the cost to us, to run the dynamo during the 70 lamp experiment, was $(\frac{460}{2240} \times 3.41 \times 6.92) + \frac{65}{4 \times 6} = 7.553$ cents per hour or $(\frac{7.553}{70}) = 0.1079$ cents per lamp per hour or $(\frac{0.1078}{8}) = 0.0135$ cents per candle power per hour.

The coal-gas company of Washington supplies gas of 17 candles power, used from a 4 foot bat-wing burner, at $1.75 per thousand cubic feet. The cost of such a jet of gas then becomes $(\frac{1.75 \times 4}{1000 \times 17}) = 0.041176$ cents per candle-power per hour, or a little over three times what the Edison incandescent light is costing us on board this ship.

I have purposely omitted the cost of labor and the interest on the money invested in the plant, as we have no additional men for running the dynamo nor engine, the officer on watch attending to it in addition to his other duties. The interest on the plant at six per cent. is only ($3500 \times 0.06 =$) $210. We use about 50 lamps about six hours a day, so that the interest on the money invested is about $\frac{2}{100}$ of a cent per candle-power per hour, or hardly worth considering.

MUD DOCKS AT VIZAGAPATAM, INDIA.

CONTRIBUTED BY COMMANDER P. F. HARRINGTON, U. S. N.

Docking.

When a ship is to be docked, she is towed up the river from her moorings to near the dockyard. A large ditch of a little more than the ship's length and breadth, and deep enough to contain water of the depth of the ship's draught, is dug in the mud at right angles to the river. At high tide the water flows into this ditch and forms a basin into which the ship is floated or dragged. Two rows of strong stakes are now driven in across the entrance to the ditch and common palmyra, date, or bamboo mats tied to them. The space between these is filled up with sand and silt, and thus communication is cut off between the dock and the river. The basin in which the vessel is now floating being surrounded by a high mud bank formed by the mud excavated from the dock, the level of the water in the basin is raised by coolies throwing some of the mud of this bank into the basin, and thus raising the bottom of the basin, which must in consequence elevate the water in the basin and the vessel floating on it. The vessel is by this process elevated considerably higher than the level of the water in the river or inlet. If the bottom of the ship requires much repair, and has, therefore, to be elevated more than usual, more earth is dug up and heaped high against the sides of the vessel, leaving two or three yards of space in the dock unfilled fore and aft, and then water conveyed thither through a small channel is baled into the aforesaid spaces. This water also enters under the vessel and elevates it to the height of the mud heaped against it on either side.

Strong beams of wood are by the following process next placed transversely under the ship at two, three, or four different places, varying according to the length of the vessel. At the spot where the beams are to be placed, a mine so called (ghanee) is dug under the vessel from side to side, coolies working from either side of the ship at the same time until they meet each other under the ship's keel. Three beams one after the other are then dragged by a rope tied to the end of each under the keel and laid there one by the side of the other. The same thing is done, fore, aft and midships, or in more places if necessary. The mud on the sides of the vessel is then dug away to the level of the surrounding ground and the sides of the vessel caulked or otherwise repaired. After this is done—or simultaneously, if the vessel is to be repaired quickly—the mud under the bottom of the vessel is excavated except near the beams and the ship's bottom repaired; and the beams also, if necessary, are removed from one place to another to allow repairs where they were originally placed. When the ship's bottom is under repair, several props consisting of the stumps of palmyra trees are placed against or slightly under the vessel to prevent her from rolling over.

Undocking.

Ordinarily four sets of hawsers are used, each being coiled into the shape of a cone, the diameter of which at the base is about five or six feet, and where it touches the vessel a foot or two less. As the coiling is going on the cone is made solid by filling it in with mud. One cone is placed under the starboard bilge forward, another under the same bilge aft, and a third and fourth in corresponding positions on the port side. Four cones are ordinarily used at

MUD DOCKS AT VIZAGAPATAM.

Vizagapatam, unless the ship is of more than three hundred tons burthen—when their number is increased according to the length and size of the ship. After this is done the transverse beams are one by one withdrawn, the dock having been first dug to the required depth, and then the vessel, which now rests entirely on these cones, is gradually lowered by withdrawing *simultaneously* from the base of each cone a coil or fake by which the four cones supporting the vessel bodily subside at a low speed and the vessel along with them. The cross-bund being now removed the water from the inlet flows into the dock and floats the vessel at high tide.

The docking and undocking of a vessel of two hnndred tons ordinarily costs about 50 rupees,* including the rent of the dock and the props and beams; and the cost increases in proportion to the size of the vessel and its draught.

Vessels of four or five hundred tons burthen have been built and undocked at this port in the manner set forth above, such as the Gallant Neil, the Lady Sale, etc.

If, on account of any extraordinary season, a sufficient quantity of water does not flow into the dock, which is very rare, four or five large casks rented or belonging to the vessel, are tied fore and aft at low water, or if large casks are not procurable, a large boat or canoe is tied on when filled with mud, and this mud being gradually removed the rising of the canoe or boats assists in getting the vessel afloat.

*A rupee (silver) is about 39 cents, and is the current coin and unit of value throughout India.

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ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

PART IX., 1883. Researches in meteorology and ocean physics in the American-Arctic archipelago by various English Arctic expeditions, from 1819 to 1854. Researches in meteorology and ocean physics during the expedition of the Vega, 1878–79, and in the winter-quarters at Serdze Kamen. Log-notes of various German vessels. Additions to the description of the eastern part of Tsugar Straits, Japanese Islands, from the report of the British surveying ship Flying Fish. Hurricane at Apia, Samoan Islands, March 24th and 25th, 1883. Comparison of the weather in North America and Central Europe for June, 1883.

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PART XI., 1883. The daily changes in the force of the wind over the land and over the sea. Meteorological and hydrographic results of the Austrian North Polar Observation Station at Jan Mayen. New deep-sea investigations; contains accounts of the deep-sea soundings of the U. S. C. S. S. Blake and the U. S. S. Enterprise in the Atlantic ocean. Comparison of the weather in North America and Central Europe for August, 1883. Hydrographic notices treating of encounter with ice in the eastern part of the South Atlantic. Plate of surveys, Chili, West Channel, by the Italian corvette Caracciolo.

BULLETIN DE LA RÉUNION DES OFFICIERS.

DECEMBER 8, 1883. Description of the Chinese ironclad Ting Huen, built at Bredof, near Stettin. The military organization of South Australia.

ENGINEER.

OCTOBER 5, 1883. The Design, Specifications, and Inspections of Ironwork: a paper read before the Society of Engineers, by Mr. H. W. Pendred.

OCTOBER 19. A New Form of Flexible Band Dynamometer, by Prof. W. C. Unwin.

OCTOBER 26. A description of the new cruisers for the U. S. Navy.

An editorial in the same number contains a wholesale condemnation of the hull, armament, machinery, and boilers of the "Chicago," concluding with the following remarkable passage: "We see in the boilers and machinery of the ship, to say nothing of the hull, a manifestation of that desire to be original at any cost which has done so much harm already in the U. S. Navy. The experience of the gentlemen who have prepared these designs can be as nothing compared with British engineers. If no such engines are to be found in a British ship, the U. S. Naval Advisory Board may rest assured that there is good reason for the fact; if no boilers of the type were ever made and sent to sea at this side of the Atlantic, the circumstance bears its lesson. Those entrusted with the design of the 'Chicago' have not availed themselves of the experience acquired in this country at a great expense, and they will regret the fact."

Notwithstanding the original argument given above, together with the assumed superior brilliancy of the English engineers, it is thought that the work of building the Chicago will still go on.

NOVEMBER 2. Peck's revolving piston pump.

A novel design of pump combining the principles of the ordinary plunger type and the rotary pump.

NOVEMBER 9. Sand-blast file-sharpener.

A description accompanied with illustrations of the operation of sharpening files by means of Tilghman's sand-blast process.

NOVEMBER 16. Giffard's Injector.

A short paper giving an easy and practical demonstration of the formulæ connected with Giffard's injector, by Prof. James Lyon.

Higgs' suspension for incandescent lamps.

A neat suspension for incandescent electric lamps, designed by Mr. Paget Higgs. This arrangement permits a considerable amount of motion to take place in the lamp, and is free from the objection to the ordinary Swan suspension, as the lamp cannot become unhooked.

Uniformity of rotation in electric lighting engines.

In considering the complaints made by electricians as to the want of uniformity in the rotation of the engine, and to the consequent want of uniformity in the rotation of the armature of the dynamo-machine, we are much inclined to think that both time and money are likely to be wasted if either is further expended in scheming elaborate cut-off and governor-gear. Some engines without anything of the kind have given a great deal of satisfaction, while others with every refinement have failed. This is the case simply from the fact that the engine in common use has been one of ample power and has been selected for contingencies, while in the refined engine, the power required has been carefully calculated and compared with the indicated horse-power of the engine. Things are, in short, in such cases cut fine, and the power of the engine at normal speed and pressure is so near the work it has to do that it must be nursed and the firing performed by a skilful fireman. For electric lighting, as well as for other dead-pull work, strong, well-made engines are required; the admission and cut-off of the steam should be tolerably quick and precise, and a powerful governor should be employed.

On the Stability of Ships at Launching.

A valuable paper on the above subject was read before the Institution of Engineers and Shipbuilders, by Mr. J. H. Biles.

NOVEMBER 23. Riveted joints.

In an editorial, discussing the relative advantages and disadvantages of hand and machine riveting, attention is called to the fact that opinions on this subject

have held sway long enough, and that it is time that some definite statement of results obtained in practice, as to the cost and efficiency of the different methods, should be made public.

NOVEMBER 30. Tweddell's hydraulic ship-riveting machine.

A description of a powerful machine for closing up rivets in comparatively inaccessible places, about the covering boards and waterways of iron vessels.

DECEMBER 7. On the Destructive Distillation of Coal and Transformation of its Nitrogen into Ammonia.

An abstract from a paper by M. Scheurer-Kestner, read before the Paris Academy of Sciences.

Armer's vertical boiler.

The object of this design is to obtain in a vertical boiler the greatest possible efficiency in the tube-heating surfaces. For this purpose the tubes have a helical twist given them, which does not influence the facility for cleaning, while it causes greater impingement of the gases against the tube-walls, and gives more freedom for expansion and contraction than straight tubes.

DECEMBER 14. Lang's wire rope.

In this method of laying wire rope, the strands and the rope are laid in the same direction, while in the ordinary manner they are laid in opposite directions. By the former arrangement a much larger wearing surface is secured, and a correspondingly increased duration; for, while in the common rope the area of bearing surface is so restricted that the outer wires break after a comparatively small wear, and before the inner part of the rope is much strained, the strands of the Lang rope continue in a serviceable condition until they are worn down too thin to resist the strain.

The First Law of Electrostatics.

A paper on this subject by Prof. Thompson, in which he shows that if electricity be considered as a self-repulsive medium, a surplus in one place and a deficit in another would give rise to motion between them, *i. e.*, attraction. This inference, as well as many other electrical phenomena, were illustrated on the same hypothesis by means of self-repelling magnet poles buoyed with cork and floated on oil. The repelling poles tend to a uniform distribution of themselves throughout the surface of the oil, which would correspond to space in nature. A surplus of poles at one place led to movement until the distribution was uniform. Prof. Thompson pursued the hypothesis to the inference that electricity is either ether or ether electrified; the former supposition being the more probable.

ENGINEERING.

OCTOBER 12, 1883. Deep-sea sounding and dredging.

Illustrations and descriptions of the following American machines at the Fisheries Exhibition, viz., Sigsbee's deep-sea sounding machine; hand sounding machine, designed by Lieut. Z. L. Tanner, U. S. N., for sounding by wire in moderate depths; and an arrangement by which a number of Negretti and Zambra's deep-sea thermometers may be attached to one line and tripped by means of a messenger. By this device a series of temperatures at different depths can be taken simultaneously on one wire by a single operation. This arrangement is the combined work of Lieut. Tanner and Passed Asst. Eng'r Bayley, U. S. N.

OCTOBER 19. Manganese bronze screw propellers.

The advantages claimed for this metal are that thinner blades may be used, and that although the first cost is greater, they are cheaper in the long run, owing to their greater life and the value of the old material.

NOVEMBER 2. Siemens' dynamo with friction driving gear.

Both belt and rope transmission are unsuitable for marine installations on account of the extent to which the electric light is used on board ship and the limited space at the disposal of the electrician. To remedy this, Mr. Raworth had invented a new method of driving electric generators by means of frictional or rolling contact. The pulley on the armature spindle is composed of disks of paper powerfully compressed between two wrought-iron cheeks and turned to a smooth cylindrical surface. It runs in contact with a large cast-iron pulley, which is also the fly-wheel of the engine, and the two are maintained in intimate connection by a pair of tightening bars. The first machines driven in this manner fed 60 lamps, and were placed on board the S. S. Aurania, where they have answered admirably.

The new system of American ordnance.

A notice of the new 6-in. gun states that the work of designing it was very systematically gone about; the quality of metal procurable, strain that such metal would endure, and the weight allowable to the gun, being all carefully studied. The most noticeable departure from European construction consists in the fact that neither the breech-block nor trunnions touch the tube. By keeping the breech-block clear of the tube, the latter is relieved of the recoil strain.

NOVEMBER 16. Prevention of incrustation in steam boilers.

The report of the Chief Engineer of the Manchester Steam Users' Association enters largely into the subject of the prevention of incrustation in land boilers. The report stated that the numerous patent anti-incrustation compounds should be used only with the greatest caution, many of them proving actually injurious to the boiler on actual trial.

NOVEMBER 30. The electric lighting of the S. S. Adelaide.

DECEMBER 7. Joicey's boiler.

A description of a locomotive type of boiler adapted for marine purposes, or for situations where great evaporative power is required in small limits. The boiler is of the vertical type, with a fire-box formed by two truncated cones united by their smaller ends. By this arrangement a space is left between the furnace and the shell, into which a man can get for the purpose of inspection and cleaning. A short barrel is riveted to one side of the shell, and a part of the upper cone of the fire-box is flattened to act as a tube-plate; the products of combustion pass through a number of small tubes in this barrel and go back through the boiler by a flue to the uptake. In a practical trial of a boiler of this kind, 5 ft. in diameter by 11 ft. 6 in. high, steam was raised in 45 minutes, and 937 pounds of water were evaporated in 40 minutes, or at the rate of 9.87 pounds of water per pound of coal. The boiler was fifteen months old, and, though it has been at work both with fresh and with salt water, it was perfectly clean and free from scale.

DECEMBER 14. The Generation of Steam and the Thermo-dynamic Problems Involved.

An abstract of a lecture delivered before the Institution of Civil Engineers, by W. Anderson, C. E.

GIORNALE DI ARTIGLIERIA É GENIO.

NOVEMBER, 1883. Artillery from its introduction to the present day. Historical exposition of development, especially in Italy.

JOURNAL DE LA FLOTTE.

JULY, 1883. The frigate Le Talisman anchored at Teneriffe, May 31. Her explorations on the coast of Morocco, between Mogador and the Canaries, have been more successful than the preceding ones. The depths of 1000 and 1500 meters have furnished us with sponges and fish in great numbers. Those of 1500 and 2000 meters have given us extremely rare fish, and living coral of the greatest value. The work has been greatly aided by the sounding-machine perfected by M. Thibaudier, the naval constructing engineer, as well as by the cable furnished by the Chatillon and Commentry Company.

Le Talisman has since returned to Palmas, where there is a valuable zoölogical museum, and thence has proceeded to the Cape Verde Islands.

SEPTEMBER 2, 1883. Le Talisman, charged with the scientific exploration of the Sargasso sea, arrived at Punta Delgada (Azores) August 17. Although the vessel has traversed the Sargasso sea in the parts said to contain the most wrack, the members of the scientific commission have not had their theories verified. It is not only in scattered bunches that the Sargasso appears for nearly 300 leagues, but in the canal that separates Pico from San Jorge there has been found at the depth of 1400 meters a fauna as abundant and as varied as that of the coast of Africa.

OCTOBER 14, 1883. The Belleville boiler. [See translation by Professor J. Leroux, of article on the Belleville boiler, in Vol. IX., No. 1, Proceedings of the United States Naval Institute.]

In view of the excellent results obtained with the Belleville boilers on the Voltigeur (despatch-boat with engines of 1000 H. P.), which, after an active cruise along the Tunisian coast and in the Levant, has been sent to the Senegal coast and the Gaboon river, the French Ministry of Marine has just ordered a set of boilers of the same system, of 2100 H. P., for the frigate l'Hirondelle, and a second set of 450 H. P. for a gunboat of the Lionne type. Besides these, MM. Belleville et Cie. are building in their shops two other sets of an aggregate H. P. of 3800, destined for the frigate Le Milan, whose engines are to work at a pressure of 10 kilogs. the square centimeter.

OCTOBER 28, 1883. Regulations governing competitive examinations for admission to the French Naval School.

DECEMBER 16, 1883. The interior sea in Tunis.

At the meeting of the Société des Ingénieurs Civils, on the 16th of November, Commandant Roudaire explained his project for an interior sea in Africa.

The projected sea will lie to the south of the provinces of Constantine and Tunis. It will occupy what is now known as the basin of *chotts*, which consists of three great depressions near the Gulf of Gabes, and which is manifestly the floor of an ancient sea; this is abundantly proved by the thick bed of salt that is found there. Commandant Roudaire scientifically demonstrates that the banks of the Melrir *Chott* are about 30 metres below the sea level.

Once flooded, the *chotts* will have a depth of water of from 22 to 27 metres, while near Sfax there is only from 1 to 16 metres.

The completion of this sea will permit the draining and purifying of a vast tract of land which is now worthless on account of the bogs and salt-deposits. Algeria will at the same time be benefited; for, the moisture-laden air will be condensed against the cold range of the Aurès, whose summits are here and there covered with snow even in midsummer. Herein will exist an advantage over the district of Provence, where the mountain ranges lie north and south, and where, as in the *chott* region of Tunis, the prevailing wind is from the south.

From a political point of view the advantage of the projected sea is that it will constitute a magnificent frontier, 400 kilometres long. It will thus serve

as a check to the Arabs, who now make frequent raids across the *chott* region, retreating afterwards with impunity to the south.

To compensate the loss by evaporation, it will be necessary to run in 187 cubic metres of water per second. The cuttings will be soft earth, and the price per cubic metre would be 50 centimes; a canal of small dimensions would be first dug, and this would be subsequently enlarged by the action of the flowing water itself to the required width and depth. The work could be accomplished in two years and a half. The total volume of cuttings would be 260 millions of cubic metres, representing an expense of 130 millions of francs. Remuneration for the outlay would come from grants of adjacent lands, whose fertility would be considerably increased; from the working of the salt deposits; from the fisheries, and from the rights of transit, etc.—*Revue industrielle.*

JOURNAL OF THE FRANKLIN INSTITUTE.

SEPTEMBER, 1883. The Screw Propeller, by Jas. N. Warrington, M. E.

In Part I. of the paper, the writer aims to present the most advanced views on the subject, with reliable formulæ for design. Remarks on the propeller with guide-blades.

Part II. discusses the problem: given a vessel with a certain resistance; required the most efficient instrument of propulsion. Comparison between the efficiencies of the guide-blade propeller and the common wheel. An original mathematical scheme for the design of a propeller, with a discussion of efficiency.

Improvements in apparatus for testing boilers.

NOVEMBER, 1883. Technical Training: an address delivered before the Alumni Association of Lehigh University, by Thomas M. Drown.

"The principal work of a technical school should be the training of young men in accurate habits of thinking and working. Without this training, the graduate is slow to adapt himself to new situations. The student who has been put through a routine course of study, abounding in the use of text-books, and in the solving of many problems, may be fairly informed as to the condition of his profession, and may have acquired good habits of study, and yet be unfit for practical work which involves principles which he has not learned.

"The proper training cannot be given in the class-room, but must be obtained in the laboratories.

"The centre around which should cluster all the teachings of a technical school should be physical and chemical laboratories; and the ruling idea of the school should be experiment and research. The time has fully come for technical schools to take this advanced position in the scientific training of engineers and metallurgists. The development of this school out of the shop has been so gradual that it is somewhat difficult to realize that the differentiation is now complete, and that the methods adapted for industrial schools do not fit the professional school. . . . . A great difficulty in teaching a growing science is that what is taught to-day may be obsolete to-morrow. A system of teaching should, therefore, be adopted which shall recognize this growth and be adapted to it; but we need not render unstable the attitude of a student by showing him that the ground on which he stands moves, and that he will be left behind if he does not move with it."

Apparatus for measuring carbon in steel.

A description of an apparatus, giving accurate methods for the estimation of carbon in steel, by Addison B. Clemence.

DECEMBER, 1883. The Cheapest Point of Cut-off, by Prof. Wm. D. Marks.

Experiments upon non-conducting coverings for steam pipes, by Prof. John M. Ordway.

An investigation into the efficiency of the various coverings used to prevent the radiation of heat from steam-pipes. Over fifty different coverings were tested, and the results show that simple hair-felt with a cover of cheap burlap proved the most efficient. It also appeared that, of the whole number tried, seventeen owed their efficiency to the hair. Asbestos is commonly supposed to have wonderful virtue in resisting heat, but it is a non-conductor only when it is in a light, downy condition and full of air. The experiments with hard-pressed asbestos paper show that it conducts heat very readily, and, in cases where asbestos paper was placed between the pipe and the hair-felt, the asbestos failed to prevent the scorching of the hair.

Pressures Attainable by the Use of the Drop Press, by Robert H. Thurston.

A paper read before the American Society of Mechanical Engineers on the magnitude of the pressures attainable in the use of the "drop press," employed in the process of "drop" forging, in the manufacture of small parts of firearms and light machinery.

A New Valve-Motion, by Carl Angstrom.

This valve-motion belongs to the same type as those of Brown, Marshall, and Joy, known by the name of "radial valve-motions." In a radial valve-motion, the motion is usually accomplished by an arm, two points of which move in different curves. One point moves in a closed curve, such as a circle or an ellipse, the motion being derived from an eccentric crank, or from the connecting-rod. The other point moves in either an open or a closed curve, and the motion is accomplished either by levers or slides, or by both combined. In the valve-motion under discussion, the chief distinguishing peculiarity is the mechanism for giving motion to the last-mentioned point of the valve-actuating arm.

JANUARY, 1884. Note on the losses per horse-power per hour, by condensation of the steam in pipes and cylinders of steam engines, by Professor Wm. D. Marks.

Water-line Defence and Gun-Shields for Cruisers, by P. A. Engineer N. B. Clark, U. S. N.

This paper, originally published in Vol. IX., No. V., Proceedings of the United States Naval Institute, has been revised and enlarged by the author, to correct certain statements made by Lieutenant Very (in "The Development of Armor for Naval Use") in regard to the curved shield, which statements are claimed to be erroneous.

Economy of the Compound Engine, by Professor Wm. D. Marks.

JOURNAL OF THE MILITARY SERVICE INSTITUTION OF THE UNITED STATES.

VOL. IV., NO. XVI., DECEMBER. How Early Did War Become an Art? By Captain R. M. Potter, U. S. A.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

No. CXXI. On masting of ships-of-war, and the necessity of still employing sail-power in ocean-going ships.

In this paper, Captain G. H. Noel, R. N., argues in favor of masted vessels as being more able to make extended cruises, and to perform the various duties of fighting ships, than the mastless vessels that form part of the naval force of England. Several improvements in the rigs of vessels are suggested: steel telescopic masts; steel tops and crosstrees; cap backstays, coming down amidships, instead of the ordinary backstays; slinging lower yards to saddles working horizontally on the lower masts—these last two improvements allowing sharper bracing of the lower yards.

Machine-Guns, by Captain Lord Charles Beresford, R. N.

Containing a description of the relative merits of different machine-guns. The great value of the machine shell-gun. French capture of Sfax. Tables are given containing the number of Nordenfeldt and Hotchkiss guns in use in the naval services of the principal powers of the world.

MÉMOIRES DE LA SOCIÉTÉ DES INGÉNIEURS CIVILS.

JULY, 1883. Note on the Interior Sea (Tunis), by M. A. Hauet.

Two commissions have had this subject under consideration; one, an official board composed of senators, deputies, naval officers, diplomats, financiers, civil and military engineers; the other, self-constituted, composed of projectors and civil engineers. The official commission is of the opinion "that there is not sufficient reason to justify the French government in encouraging the enterprise."

M. Hauet argues at length against the feasibility and propriety of the scheme of attempting to create an inland sea, as proposed by the second commission.

MITTHEILUNGEN A. D. GEBIETE D. SEEWESENS.

VOL. XI., NOS. VII., VIII., 1883. Hotchkiss and Nordenfeldt guns, by J. Schwarz, Austrian Marine Artillery.

Describing the changes and additions made during the past year; with tables, giving weights of guns, projectiles, charges, initial velocity, force of impact, etc.

Kapeller's Deep-Sea Thermometer, by Professors Wolf and Luksch.

The reservoir of mercury is protected from bathic pressures by a vessel of mercury surrounded by a layer of copper filings. Between four and five minutes is given as the time required for the thermometer to give a reliable reading. Other deep-sea thermometers require as much as twelve minutes.

Description, with plates, of boat-rigs in the Netherlands navy. The methods of determining the time of true noon, by equal altitudes of the sun, in the 18th century. New ships for the Brazilian navy. Launch of the Chilian cruiser Esmeralda. The Haytian navy. Deep-sea soundings (U. S. S. Enterprise, Commander Barker).

A list of fifty-three soundings between Cape de Verde and the Cape of Good Hope.

Project for the erection of lights and electric signal stations in mid-ocean.

VOL. XI., NOS. IX., X. Tables for the reduction of observations of wave-flow, by Professors Luksch and Wolf. Return of the Austrian Arctic expedition from Jan Mayen Land.

An account of the wintering on Jan Mayen, from July, 1882, to July, 1883. The station was one of those provided for by the International Polar Com-

mission. Interesting details are given of the climatic and meteorological conditions of the island.

Howaldt's plate-bending machine. Coast defence of Russia. French armored ships of the first-class. The Belleville boiler.

VOL. XI., NO. XI. The position of the merchant marine in time of war. The ocean currents of the South Atlantic. The Russian use of torpedo-boats. McEvoy's one-wire system for submarine mines (trans.). Stilling waves by means of oil (trans.). Collation of observations upon the heating power and other properties of various kinds of coal. Submarine locomotion.

PROCEEDINGS OF THE INSTITUTE OF CIVIL ENGINEERS (LONDON).

1882-3, PART IV. Raising the S. S. Astral.

The Astral is the largest vessel of the Orient Steam Navigation Company's line of steamers trading between London and Australia. Her dimensions are: length 455 ft., breadth 48 ft., depth of hold 37 ft., gross tonnage 5588.

The Astral while coaling in Neutral Bay, Port Jackson, Sydney, filled and sank. Her lower coal-ports were open, and she was taking in coal on the starboard side; the water ballast, provided for ensuring stability at such times, had been removed from the double bottom; as the coaling proceeded, the side of the vessel gradually went lower till some of the port-sills were brought under water, of which a great quantity poured into the hold. The Astral went down stern first in about 52 feet depth of water at the stern, and rather less forward, settling with a list of 11° to starboard. At the time of going down, 200 tons of iron and 1500 tons of coal were on board.

To raise the vessel, a coffer-dam was constructed 410 ft. long, 30 ft. deep, and furnished with a central transverse bulkhead. The coffer-dam was made on shore in completed sections, each 16 feet in length. These sections were weighted, lowered into position, and attached to the vessel by bolts passing through the side-lights. Instead of caulking, canvas was used to make watertight joints; this was tacked on with sufficient slack to allow for contraction. The amount of canvas covering was 26,000 square feet.

Steam pumps were set to work on the 27th of February, and on the 1st of March the vessel, having risen and righted sufficiently, was taken in tow to shallow water and grounded on the top of flood-tide. As the tide ebbed, the coffer-dam was removed. Pumping was then continued, and the vessel was in due course of time trimmed preparatory to going into dock.

This method can of course be most successfully applied in comparatively sheltered situations.

RIGS OF VESSELS, by Captain R. B. Forbes.

In his pamphlet on the rigs of vessels, Captain Forbes gives in an entertaining manner some personal reminiscences, and argues in favor of several radical changes in the rigs of deep-water ships and coasters.

RIVISTA MARITTIMA.

OCTOBER, 1883. Naval appropriations. Collisions at sea. The battle of Port Said; a story of the future (trans.). Our prospective dockyards. The new cruisers of the United States (trans.). The Chilian Navy. Sailing vessels for instruction. International rules to prevent collisions at sea.

NOVEMBER, 1883. Naval appropriations. The disasters at Ischia and Giava. Polar expedition of the Dijmphna. The battle of Port Said (continuation). Strength of the French fleet. Application of electricity on board vessels-of-war. Improvised life-buoys and life-rafts.

SCIENTIFIC PROCEEDINGS OF THE OHIO MECHANICS' INSTITUTE.

SEPTEMBER, 1883. Mechanical Notes, by Harry M. Lane. 1. Friction of slide valves. 2. The slide valve as a water relief valve. 3. Compression and cushion.

Note on the Purification of Drinking Water. By Dr. F. Roeder.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

OCTOBER, 1883. Papers read at the Troy meeting. The colorimetric determination of combined carbon in steel. Roessler's method of manufacturing sulphuric acid and sulphate of copper.

TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

VOL. XII., NOS. CCLXI., CCLXII. On the current-meter, showing the reason why the maximum velocity of water flowing in open channels is below the surface. With plates and diagrams.

NO. CCLXIII. Paper on the rebuilding of the Monongahela bridge at Pittsburgh, Pa. With plates and diagrams.

TRANSACTIONS OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

DECEMBER, 1882. The Channel tunnel.

Mr. Charles Tylden-Wright, F. G. S., after a visit to the experimental works at Dover and Saugatte, gives an interesting description of the progress made in the trial-heading, which, on the English side, has been carried 2030 yards under the sea. It is proposed to carry the tunnel through the gray chalk stratum, at a depth of not less than 150 feet below the bed of the sea; and it is confidently expected that the number of "breaks" in this stratum will be inconsiderable for the whole distance between the English and French coasts.

The tunnel can be finished in four years, at the longest (according to Sir Edward Watkin, in charge of the experimental work), and at a cost of £3,000,000.

Arguments are brought forward in favor of two tunnels, as lessening the inconvenience attendant on accidents; and the author takes ground in favor of compressed-air locomotives for hauling *débris*, and for permanent traffic.

THE UNITED SERVICE GAZETTE.

NOVEMBER 24, 1883. Liardet's detaching and attaching gear for ships' boats.

The apparatus consists of tumbling blocks in the bow and stern of the boat. "The advantages claimed by the patentee of this gear are as follows: Simplicity

and fewness of parts, there being only three in it, two of which are movable, but not accidentally detachable. *It is perfectly under the control of one man, and he the one in charge of the boat.* The gear is unhooked, and the boat detached by the letting go of a single line. It can be hooked on or detached with the greatest ease in the darkness, and, from the fewness of its parts, it is so simple that its use is obvious to every sailor." The Commissioners of the Fisheries Exhibition awarded the prize medal to the inventor as being far in advance of all other competitors.

THE UNITED SERVICE GAZETTE.

DECEMBER 15, 1883. Improvements in Appliances for Exhibiting Lights of Ships at Sea, by Mr. John Evelyn Liardet.

Mr. Liardet's system consists of the permanent, or standing lights: masthead white; lower red and green; and stern blue; and two other masthead lights, one red and one green, which are acted on entirely by the rudder. "Thus, when it is desired to show the green lights, the masthead red light is immediately shut off, and the ship will be showing her masthead white, green, lower green, and stern blue lights . . . . The masthead green light would be shut off when desired to show the port red lights, and the ship would be showing her lower permanent port red, masthead red and white lights, and stern blue light."

The light signals are effected by Mr. Liardet's system, and application of electricity.

ADDITIONS TO LIBRARY.

EXCHANGES.

American Chemical Journal, Vol. 1, No. 1, to Vol. 5, No. 5, inclusive.
Annalen der Hydrographie u. Maritimen Meteorologie. Nos. 9, 10, 11, 1883.
Bulletin of the American Iron and Steel Association. Weekly.
Bulletin de la Réunion des Officiers. Sept. 22, No. 38, to December 29, No. 52.
Giornale di Artiglieria é Genio. Part 2, Nos. 9, 10, 11, 1883.
Journal de la Flotte, Sept. 9 to Dec. 23, 1883.
Journal of the Franklin Institute, Nov., Dec., 1883, Jan., 1884.
Journal of the Military Service Institution of the United States. Dec. 1883. Vol. IV., No. XVI.
Journal of the Royal United Service Institution. Vol. XXVII., No. CXXI.
Mémoires de la Société des Ingénieurs Civils. Nos. 7, 8, 9, 10, 1883.
Mittheilungen a. d. Gebiete des Seewesens. Vol. XI., Nos. 7, 8, 9, 10, 11, 1883.
Norsk Tiddskrift for Sovaesen. Oct., Nov., Dec., 1883.
Proceedings of the Institution of Civil Engineers (London, England). Vol. LIX., Pt. I. to Vol. LXXIV., Pt. IV. 1879–83.
Proceedings of the Institution of Mechanical Engineers (London, England). No. 3, July, 1883.
Rivista Marittima. Nos. 9, 10, 11, 12, 1883.
Scientific Proceedings of the Ohio Mechanics' Institute. Vol. 2, No. 3.
Transactions of the American Institute of Mining Engineers.
Transactions of the American Society of Civil Engineers. Aug., Sept., Oct., 1883.
Transactions of the North of England Institute of Mining and Mechanical Engineers. Vol. XXXI., Pt. V., 1882, to Vol. XXXIII., Pt. I., 1883.

DONATIONS.

Problem of Interoceanic Communication by way of the American Isthmus. By John T. Sullivan, Lieutenant, U. S. N. From the Author.
Publications of the United States Artillery School, Fort Monroe, Va., embracing:
- Standing Orders for the United States Artillery School.
- Regulations and Programme of Instruction.
- Course on Military Communication. Part I., Military Bridges. By James Chester, Captain, 3d Artillery.
- Course on Military Communications. Parts II. and III., Roads and Railroads. By James Chester, Captain, 3d Artillery.
- Course of Topography. Part I., The Practical Study of Surveying Instruments. By the same author.
- Course of Sciences applied to Military Art. Part IV., Metallurgy of Iron. By Constantine Chase, 1st Lieutenant, 3d Artillery.
- Chemical Manipulations. By John P. Wisser, 1st Lieutenant, 1st Artillery.
- Artillery Exercises: Description and Service of Machine Guns. By John H. Calef, Captain, 2d Artillery.
- Course of Artillery: Ballistics. By James M. Ingalls, Captain, 1st Artillery.
- Instructions in Photography. By Lorenzo Lorain, late Major, 1st Artillery. Revised by Henry L. Harris, 1st Lieutenant, 1st Artillery.

Rigs of Vessels. By R. B. Forbes. From the Author.
The Great Admiral. A Poem. By H. L. Koopman. From the Author.